POPULATION, ENVIRONMENT, AND DEVELOPMENT

POPULATION, ENVIRONMENT, AND DEVELOPMENT

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FOREWORD

Considerable debate has taken place in recent years on the complex issue of the environmental implications of population change. Since the 1994 UN International Conference on Population and Development, which produced a detailed 'Program of Action' for stabilizing world population and achieving sustainable development, several forums have been held to explore the linkages between population and the environment. Of particular note was the *Conference on Population, Environment and Development*, organized by the Tata Energy and Resources Institute – North America (TERI-NA) on 13–14 March 1996 in Washington, DC.

This book includes a collection of papers from eminent scholars in the field who attended the TERI conference, and reflects the diverse nature of the issue. It also includes discussion and debate on environmental subjects such as water scarcity, deforestation, biodiversity, and global warming, and social issues examining consumption patterns, energy policy, and migration. This compilation succinctly highlights the need for concerted efforts at all levels – local, national and global – to deal effectively with the environmental problems that face our planet. It also reinforces the need to take a comprehensive view of the economic development process, as a whole, and consumption levels, in particular, when evaluating the impacts of population change.

World population is growing at an alarming rate, and developing countries exhibit the highest rates of growth. While the problem of rapid population growth is one faced primarily in developing nations, the problem of environmental impacts and of pressure on resources has to be confronted in both the developing and the more developed countries. Patterns of production and consumption in the developed countries have been the principal source of pressure on the environment. Population growth in developing countries, in particular, multiplies the much lower per capita effects of growth in their economies.

Sustainability cannot be achieved merely by limiting population growth. Sustainable development is based on the premise that population and per capita consumption must operate within the capacity of the global ecosystem to respond indefinitely to our demand on resources and to assimilate the wastes produced. While large populations exert considerable stress on their ecosystems, small populations with high rates of consumption can eclipse the effect of larger populations operating at much lower rates of consumption.

The papers in this book focus on the many structural features of economic activities and population changes, which determine the extent and nature of environmental damage and pollution. For example, we have several varying examples of communities and societies living in harmony with nature, on the one hand, despite the density of population, while others, even though sparsely distributed, wreak havoc on natural resources and the environment around them. This raises important questions about different patterns of growth and development and the manner in which production and consumption of goods and services takes place in various parts of the globe.

The need to reverse the current trend of deteriorating environmental conditions is widely accepted by the authors. This requires the stabilization of the population size in order to attain a sustainable balance between the people's consumption levels, on the one hand, and the health of the ecosystem which supports them, on the other. The environment has to sustain not only the basic human needs for survival, but also the conversion of raw materials into products and services. The past few decades have produced a tremendous increase in population, especially in the South, coupled with the destruction of forests, soil erosion, water pollution, deterioration in the quality of air, overcrowding, and excessive solid waste generation, to name a few. To halt such a decline in the quality of life, there is a necessity for farsighted population policies that address the issues of malnutrition, status of women, and education. But there is also an urgent need for further research in the area of ecoefficiency and renewable energy technologies. Nations need to look beyond their boundaries and address environmental problems from a global perspective. Many of the scholars featured here recognize this and call for international cooperation on issues such as technology transfer, trade, and protection of the environment.

This book will contribute to the ongoing dialogue on these issues and serve as an inspiration for further research into the issues that are shaping the future of humankind.

Maurice Strong
Senior Adviser to the President, World Bank
Chairman, World Resources Institute

PREFACE

The issues of population, environment, and development should be treated not as separate sets of issues, but as three interactive forces. Policies should be designed in view of the complexity of the interrelationships among these elements. The Tata Energy and Resources Institute, Washington, DC, organized a Conference on Population, Environment, and Development on 13 and 14 March 1996 at the Carnegie Conference Center, Washington, DC, to address these issues. A set of accomplished authors from across the globe were invited to prepare theme papers that were presented at the conference. In addition, some of the best researchers in the field were commissioned to participate in the discussions and deliberations. The focus of the conference was oriented towards the developing world, which faces the challenge of achieving high economic growth rates while taking account of sustainability considerations. This book is a compilation of the papers[1] and two luncheon addresses presented at the conference. All the papers have been reworked through several rounds of editing.

The volume begins with the inaugural address delivered at the conference by Dr Emil Salim, former Minister for Environment and Population, Indonesia. The first few papers define the population problem and set the stage for the following papers. The two successive papers deal with the issues of deforestation, biodiversity, and migration, specific to the Philippines and Indonesia. Following these, the issue of water scarcity, with emphasis on the elements of water stress in the Middle East, is discussed. A case study from India reviewing the issues of poverty and environmental stress in India, as a whole, is presented next. This is followed by an analytical paper on the behavior of the population, environment, and development (PED) variables at the district level, succeeded by an examination of the PED nexus in Nepal. The ensuing paper describes the Chinese achievement in 'fueling' the world's largest population. The social issues that emerge in the conception of a developmental project are elaborated in the next paper. This is with reference to the construction of the Tehri dam in India. The dynamics of conflict arising from population and environmental stress, and the issues of global warming, and life-style and technology follow in the subsequent set of papers. Two luncheon addresses presented at the Conference have also been reproduced with some modifications. The valedictory address by Mr Tim Wirth, Under Secretary for Global Affairs, US Department of State, appears after the luncheon addresses. Finally, a summary of all the papers is presented in the epilogue at the end of the book.

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[1] The paper by Joel Cohen entitled *How Many People can the Earth Support* was not presented at the Conference. It has been included in this volume with the permission of the publishers, W W Norton & Company.

R K Pachauri
Lubina F Qureshy

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We would firstly like to acknowledge our production editor, Ms Meena Srikumar, for the immense effort that she has put into this volume. We are very grateful to the authors for their patience, encouragement, and support through the various rounds of editing, and to the panelists and chairpersons, whose comments have been most valuable in preparing the epilogue to this book[1]. We are thankful to Mr T Radhakrishnan for his production assistance in the design and layout of the book, to Mr R K Joshi for graphic assistance, and to Mr Sabari Nath, Ms Kavita Verma, and Mr T P Sankar for their technical support. Finally, we would especially like to thank the MacArthur Foundation, Chicago, the United Nations Population Fund (UNFPA), New York, and the Summit Foundation, Washington, DC, for their support in funding the Conference.

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[1] The list of panelists and chairpersons is presented in the Epilogue.

INAUGURAL ADDRESS

Emil Salim[1]

Ladies and Gentlemen, I would like to elaborate on the subject of this conference – population, environment, and development – by giving a brief example of what we encountered in the 1960s when Indonesia was listed among the sick countries of Asia. The economy was grossly mismanaged. It suffered from a huge budget deficit, much larger than the current US deficit. Its exports were sluggish; it could not pay its foreign debts; and it stood out of the United Nations. The country was heavily dependent on imports, especially in food - 75% of the world's marketable surplus in rice was imported by Indonesia. The economy was stagnant, the infrastructure was disarrayed, and the rate of inflation was as high as 650% per annum. On top of that, we had a high rate of population growth of 2.6% per annum. 87% of the total population lived in rural areas. There was large-scale unemployment. The environment was completely out of focus. We overexploited our forest resources, depended heavily on oil, and the economy was highly resource based.

Fortunately, at the end of the 1960s, we had an opportunity to change the economy. One important change was in terms of achieving macro-economic stability. We aimed at a zero, or low, inflation rate to get the economy in order. We moved towards an export-oriented economy, tried to achieve self-sufficiency in the production of rice, and built up the agricultural sector, on which 87% of the population depends. Thus, we built up a strong domestic economy by moving into an agro-based, import-substitution industry, and, finally, into an export economy. The results were very satisfactory. In a short period of less than 3–4 years, inflation was under control, almost below 25%, and is now below 10%. Exports, too, grew at a rapid rate.

Strong efforts were made to attain stability in the level of population. The aim was to achieve stable population levels by the year 2020. One means of achieving this objective was to set the norm for a two-child family. In addition, the state laid emphasis on improving family welfare levels. This requires a concerted effort incorporating health facilities, education, increasing employment ratios, and compulsory education till the primary school level. These facilities must spread at least within a 5 km radius. In particular, the welfare measures should incorporate village welfare. At the village level, it is possible to choose intellectual and influential people from religious groups, from women, and from the youth in that area, in order to facilitate welfare development. The next step is provincial welfare development. Therefore, from family planning, there is a move towards family welfare, followed by village and provincial welfare, and finally, towards national welfare. Thus, family planning has never been an isolated activity in Indonesia, and has been a part of a global and national level welfare strategy. Under family welfare programs, families with 2 children are given preferential treatment in terms of getting education, housing, and financial support. It is important to inculcate the feeling that a two child family is the most desirable for a country. This was in contrast with the six-child family norm of the 1970s.

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[1] Former Minister for Environment and Population, Indonesia.

We now move on to the environment. When we talk of family welfare, what does it signify? It signifies clean water and sanitation. Clean water, in turn, is linked with religion. A Muslim family likes to pray. Before they pray, they have to wash their hands to clean themselves with clean water. Clean water requires clean rivers. Clean rivers are ensured by forest cover or plantations of trees. In this way, there is an incentive to plant trees to ensure clean water for praying and, thereby, ensure a clean environment.

Thus, the whole environment dimension is woven into the behavioral pattern of the local people. In this way, it is possible to come up with clean villages, clean provinces and clean cities. Indonesia, in fact, has a clean city drive, where the cities which satisfy the 'clean' criteria are brought to the palace of the President on the fifth of June to be recognized as the cleanest cities of Indonesia. However, in our efforts to clean the environment, we must look beyond the physical environment.

The above micro environmental approach needs to be complemented with macro-level efforts. Micro environmental management efforts have to be incorporated within the framework of macro environmental management. Prices should be set at competitive levels. Subsidies should be avoided in the rural and food sector. Water should not be treated as a free good and its price should be set competitively. In this way, the principles of economics should be incorporated into environmental decision making.

This brings us to an important phrase of ecology – economic sustainability. We have to look at three sides of sustainability – ecological, social and economic. Ecological sustainability considers the use of resources on the basis of their sustainability. Social sustainability is concerned with the social development of the nation, where population growth is seen in relation to the capacity of the natural resources. Social sustainability ensures that social practices are not harmful to the physical environment. Finally, economic sustainability requires a sound economic policy with minimal deficit in the country's balance of payments, which could be brought about by reducing the inclination towards imports. Economic sustainability also advocates an export-oriented economy, with sufficient foreign exchange reserves, a minimum balance which can finance imports for six months and ensure that the economic climate is not favorable for external debts. Concomitant with the three aspects of sustainability are the three sets of goals of economic, political, and social stability; economic, social and ecological development; and, ecological, social, and economic equity. These have been the three building blocks of development which Indonesia has pursued for the last 25 years. The results of this pursuit were very satisfactory. We managed to bring down the rate of growth of population from 2.6% to 1.3% per annum and we are aiming to achieve stable population levels by 2020.

The level of social development in Indonesia has also been satisfactory. Up to the age of 13, all children are given compulsory education. Primary health facilities have been taken down to the village level. We have also succeeded in bringing the mortality rate to a reasonable level. The percentage of people living below the poverty line also dropped from 60% in the early 1970s to 17% of the total population in the 1990s. The government is working towards further reduction in the poverty level by providing financial assistance to those falling under this category.

This is, in brief, the story of Indonesia's progress. You may wonder why I narrate this. It is not to show off our achievements, but to get across the message that a country with a high rate of inflation and population growth, a country which had been misusing its environment, can make a difference. It can change provided it has the right opportunities and Indonesia was fortunate in this respect. We managed to repay the huge debt of US $3.5 billion. We were also offered fresh foreign aid from a consortium of Government assistance.

Therefore, we achieved our targets not only through our efforts, but with the cooperation of other countries. We now belong to the middle income group of countries, although on the lower level. Now that we belong to the middle income group of countries, we look back to our colleagues in the low income countries.

One such country, with whom we have very good relations and which is also a part of the nonaligned movement, is Mozambique. Mozambique has the lowest per capita income of $80. Its population is 17.5 million with a rate of growth of 2.7%, in the same range as that of Indonesia 25 years ago. At the same time, however, Mozambique has a high illiteracy rate of 76% and a low life expectancy rate of 48 years, again similar to that of Indonesia 46 years ago. 80% of its population is rural. The country has a huge loan credit of US $5.5 billion. The corresponding figure for Indonesia in the 1960s was of the order of US $3.5 billion. However, despite the fact that their debt service payment is 25% of their total export earnings, which is the same as ours, the net present value of the debt service is more than 1000% of their export earnings. Whatever comes in as export earnings is used to repay debts, just as we did. The country suffers from widespread poverty, requiring rehabilitation. Its exports are dwindling and it has massive deficits. The only difference in the two countries lies in the period of crisis. The crisis period for Indonesia was the 1970s, whereas Mozambique faces this crisis in the 1990s. Whereas in the 1970s, it was possible to obtain aid, in the 1990s the situation is different. In the 1970s, everybody was willing to consider foreign aid to Indonesia and the resettlement of its debts. Today, they refuse to settle Mozambique's debts and insist on full repayment even though we know that it is impossible for Mozambique to fulfil this.

Thus, here we have a situation of two countries facing very similar sets of issues. The only difference is that Indonesia faced these sad circumstances in the 1970s, which was a relatively fortunate period, as compared to the 1990s, when Mozambique faces a similar crisis. Mozambique, therefore, faces the daunting task of repaying its debts by exhausting all its export earnings. Moreover, it would not be possible for its economy to accumulate public savings, when it does not have the resources to even meet its basic needs.

This is, indeed, a pitiable situation. At this time, the US is busy with the next elections. Nobody seems to be worried about the fate of the poor people. When we discuss here the issues of population, environment and development, I have one clear message to offer. If a country is given a chance to overcome its population, environmental, and developmental challenges, it can make it. I am confident that my friends in Africa can do the same if they have the sympathy and the support from the world over. Thank you.

FROM STOCKHOLM TO RIO AND BEYOND

R K Pachauri[1]

Ever since the first conference on environment and development – the 'United Nations Conference on Human Environment' – was held in Stockholm in 1972, the global community has increasingly focussed on environmental protection and its relationship with economic development in several actions and programs. These concerns came into sharper focus during the Rio Summit in 1992, and now that five years have gone by, the United Nations (UN) is in the midst of extensive preparations to discuss progress with the various initiatives and programs that were launched during the Rio Conference. Much of the deliberations and actions that the General Assembly would go through are likely to deal with crosscutting issues, the most critical of which deal with issues of population, environment, and development.

At the time of the Stockholm conference, population issues were very much part of prevailing international and national concerns. However, this subject was not included explicitly or otherwise in the agenda of the Stockholm meet, and references to population in the context of environmental subjects at Stockholm were either cursory or anecdotal. This sectioned view of population policies at the time may have been the result of an incipient stage of analysis and knowledge in a field that was only then beginning to attract the attention of social scientists in general and economists in particular. Population policies and related economic analysis at the time tended to be an extension of the 'controlling population' syndrome prevalent at the time. It would be useful to explore whether economic analysis has progressed in the past quarter century since Stockholm, and now that Rio is five years behind us, to ask 'where do we go from here in analyzing the triangle of population, environment, and development?'. The need for the assessment of past efforts, present options, and future prospects is all the more important today because population policies in any particular country cannot be regarded as isolated

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[1] Tata Energy Research Institute, Darbari Seth Block, Habitat Place, Lodhi Road, New Delhi - 110 003, India.

from national as well as international developments, with the growing interdependencies within the global economic system and the increase in international communications that has taken place in recent years.

Population policies must be directed to the achievement of human welfare and progress according to established criteria generally accepted by any society. Even though economists have, particularly in the last 20 years, focussed their attention on the economics of population control measures, a general lack of relevant data and the more serious shortcomings in the tools of analyses developed by researchers have hampered the spread of knowledge on this subject. A wide dissimilarity in the methodologies used by medical doctors, demographers, and scientists on the one hand, and economists on the other, has also contributed to a lack of appreciation of the concepts relevant to evaluation of population policies.

The extensive period for which fertility control measures affect the population of a country (and consequently, the economic welfare of its people) warrants the evaluation of alternatives in a long-run dynamic context. In this regard, the reduction in mortality rates worldwide merely extends the period over which births (or their nonoccurrence) would make an impact on the economic well-being of any society. Whereas measurement of the actual costs and benefits of different population policies and measures must necessarily be specific to a particular society, the conceptual basis for evaluating various alternatives is sufficiently general to qualify for common treatment and analysis. In developing such a conceptual framework it would be useful to review some of the prominent work done in the field, going back to a period when economists began focussing on these issues. The generality of application of these concepts, however, does not detract from our major concern and orientation which is towards explaining the dynamic effects of population policies with particular reference to the developing countries of the world, since they are faced with challenges of staggering dimensions in devising and implementing measures to cover the interaction of vast populations with the environment and strategies to increase the economic welfare of their societies, while protecting their natural resources.

A useful survey and summary of initial work done in the area of the economics of population growth was presented by Robinson and Horlacher (Coale, Hoover 1958). They appropriately distinguished between a generalized approach on the subject dealing with a wide consideration of costs and benefits of population-related measures against the use of cost-effectiveness as an alternative. Economists would generally prefer to use the larger cost—benefit approach taking into account the direct as well as indirect costs and benefits of a particular project and then computing the present values of all the possible streams pertaining to these that would occur in the present as well as the future. In effect, the present values of all benefits are compared with the present values of all costs, and if the former is greater than the latter, the project or scheme under evaluation is regarded as desirable. However, economic issues and analysis in this field must include externalities such as environmental impacts of population changes and consumption patterns. A limited assessment of cost-effectiveness, on the other hand, concerns itself only with costs based on certain specified outcomes and goals that may be laid down. The analysis then merely attempts to evaluate all costs associated with achieving the specified target using the various alternatives being evaluated. The use of simple cost-effectiveness studies has naturally been widespread since it relieves policy makers, program administrators, and medical doctors of the complex task of identifying and quantifying all the direct and indirect benefits and costs that would accrue to society as a result of any particular set of population-related measures. But this approach, even though simple and convenient, overlooks the important economic effects that policies and programs would have on society as a whole in the long run.

One of the earliest applications of the cost–benefit approach to family planning is ascribed to Stephen Enke (1960). In a series of studies, he developed estimates of costs and benefits to society associated with the prevention of births. One such set of estimates was based on the evaluation of an individual's lifetime production in India and the lifetime consumption of an additional birth in that country. He found the latter to exceed the former by Rs 6000. A naive interpretation of such numbers without allowing for the time value of money can be misleading. Enke, therefore, used a rate of discount of 10% and calculated that since a newly born individual would not produce anything till the age of 15, the present value of his future production discounted to the year of birth would be very close to zero. Nevertheless, consumption by the newborn commences immediately after birth, and, therefore, the present value of the stream of all future consumption would certainly not be a negligible amount. He estimated this to be approximately Rs 690, but presumably no externalities or environmental costs were included in this amount. Enke then allowed for the fact that this amount could have been reinvested if it was not spent on consumption, and with a capital–output ratio of 4 over a 10-year period, would have resulted in benefits that add up to make the present discounted value of birth in India a total of Rs 1000. Enke used different variations and refinements to this approach in later studies but we would not discuss them here to keep the analysis reasonably simple. Some researchers have attacked Enke's and other studies on the grounds that the assumption of a total absence of production in the first 15 years of life is not relevant to developing countries, where children are known to help in farming and other productive activities relatively early in life. This assumption was correctly specified in a similar study by Meier (1959), who assumed that a child starts producing at the age of five years. This and other methodological differences led to Meier's estimates of the present value of a birth prevented being less than Enke's estimate. But irrespective of the numbers used, the important issue to consider is that fertility decisions in many developing countries are based on the rational expectation that with early participation of children in productive or income-earning activities, the net benefit of additional children to parents is often positive even under adverse, low-income conditions. What would be useful is to carry out such analysis in a developed country context, specifically including environmental costs (local, regional, and global) associated with high levels of consumption, as occurs in high-income societies.

The naive and simplistic implication of the above so-called investment-model approach is that society would be justified in making an incremental expenditure to prevent one birth up to the present value of net benefits from preventing that birth. Program administrators may be generally aware of this concept, but methodological problems arise in the choice of items which must be included as costs or benefits, the timing of their occurrence, and the choice of discount rates. For instance, Enke's analysis was clearly sensitive to the timing of production as commencing 15 years after birth, and his estimate of Rs 690 was biased upwards on this account. A lack of knowledge of causal factors that affect the streams of costs and benefits used in the analysis can also lead to shortcomings in the results obtained and conclusions derived therefrom. This is illustrated by one of the conclusions reached by Meier in his study, namely that the value of medical innovation that reduces infant mortality would be negative in developing countries. This deduction of Meier completely ignores the link between infant mortality and higher birth rates, which depends on the fact that couples base their choice of fertility on a model of decisions under uncertainty – the higher the level of infant mortality in a society the higher (disproportionately) the birth rate based on this logic. Reduced infant mortality cannot, therefore, be regarded as negatively valued in isolation of its effects on fertility decisions.

In a macroeconomic setting, the identification and evaluation of costs and benefits related to population policies and birth rates is a fairly complex problem. In the investment-model approach of Enke and Meier, the value of an additional birth (either positive or negative) is reckoned in terms of the net contribution an additional individual in society would make over and above his own consumption or subsistence requirements. This approach, of course, ignores the fact that parents (who generally bear the cost of raising children) do derive some utility or satisfaction of a human need from raising children. If fertility decisions are based purely on economic rationale, then the implication of this approach would be that socially-based and government-run programs do not generally include as benefits the utility benefits that individuals would gain from each child that they raise. Some researchers advocate national population policies on the premise that in developing countries in particular family size was larger than the optimal because couples either lacked awareness of their welfare – maximizing family size – or were poor managers of contraception. While we accept the possibility of the latter reason, we find it difficult to support the former argument. The major force in the argument for society-based population programs, in our opinion, lies in the various 'externalities' that an individual's fertility effects impose on society as a whole. Additions to the population compete for scarce resources – for land, for employment, for education and employment, etc. For instance, the aggregate demand for fuels and energy in rural parts of India is, in some cases, significantly responsible for the large-scale deforestation that has taken place. The per capita land area of forests in India is 0.14 hectares as compared with the global average of 1.6 hectares. The burden of these 'externalities' is distributed over society as a whole and not merely on the parents of the child. If allowance is made for these social effects or externalities, then in our evaluation of a program the inclusion of all private and social costs as well as benefits becomes necessary. The streams dealing with these flows would now include the flow of taxes and monetized savings generated by an individual over his lifetime as benefits and the flow of society's outlays to provide services such as health, education, transport, etc., as costs. However, government programs can, at best, facilitate decision making through creation of knowledge and awareness, and by pricing of resources to include all externalities.

Economists have generally considered social programs and their merits in terms of aggregates. The importance of distribution effects in population policies can hardly be overemphasized. A prolonged neglect of the dynamic effects of births and their prevention on income distribution in various countries has led to imbalances in population programs which result in the accentuation of inequities in economic and social development, particularly in the Third World. The problem has been compounded by a concern with only direct costs and benefits of cost-effectiveness which would naturally reveal that preventing a birth in a densely populated and accessible urban area is far lower in terms of direct costs than largely inaccessible rural areas in a country. Similarly, neoclassical approaches in formulating and evaluating fertility control programs have concerned themselves with benefits in terms of increases in aggregate output or average per capita income, without regard to the distributive aspects of such income increases. Quite typically, as a result of this approach, programs have been developed and implemented to aid those areas of the population where the private individual's decisions to restrict fertility exhibited little deviation from the socially optimal pattern.

The importance and extent of distributive imbalances in population policies and trends as they exist in most cases, has been brought out in a number of studies based on macroeconomic models of growth. Almost four decades ago, Coale, Hoover (1958) carried out a study of India using a detailed macroeconomic growth model in order to measure quantitatively 'the economic significance of a reduction in fertility'. They used their model to arrive at outcomes of different population growth projections for five-year periods between 1956 and 1986. Understandably, the rate of growth of per capita income was found to decelerate under assumptions of high rate of population growth and to accelerate under assumptions of low rate of population growth. Total income also grew faster under the low fertility assumption, because with higher per capita income in the latter case, the savings ratio was higher, leading to greater investment and overall growth. The really significant question arising out of this study was however, brought out in a similar study by Demeny (1965) in which the gains from income increases were shown to accrue to families that were directly affected. One major beneficiary of population control is, of course, the government which has to now bear fewer social costs such as for education, public health, etc. But, by concentrating on urban areas, the benefits of most programs are passed on to urban populations, who, with higher incomes, have higher savings which lead to faster growth in the future. Income disparities between urban and rural areas are, therefore, further accentuated, and no amount of socialistic sloganeering can conceal the fact that clinic-based and urban oriented population control programs as they exist today are not only suboptimal in terms of maximizing society's overall welfare but also distort income distribution in developing countries even beyond existing levels.

A preoccupation with cost-effectiveness coupled with an urban orientation in designing and administering national programs can, therefore:

- completely ignore social costs and benefits related to population control based on a narrow concern for the budgetary components of such programs;
- lead to a suboptimal utilization of resources for promoting economic welfare;
- increase disparities in income distribution in the long run; and
- ignore the linkages between population, development, consumption, and the effects on the environment.

One cannot, at the same time, overlook the logic of urbanized clinic-based programs which are relatively easy to organize with a given administrative structure. The lack of literacy, transportation, communications, and housing facilities in rural areas necessarily results in a smaller 'bang for the buck' than in urban areas. Investments in these infrastructural facilities must often precede population programs making them less cost-effective than in urban areas. With governments increasingly concerned with the benefits of overall rural development, it becomes necessary to regard population policies as only one component of a multipronged approach, to ensure that investments in transport, education, health, etc., lead to benefits in a wide range of activities.

In recent years, several development-related subjects, which were generally neglected in the past, have been elevated to a level of widespread debate. The various summits held in Cairo, Copenhagen, Beijing, and Istanbul in recent years have covered a range of subjects embracing population and development, women's role in development, social aspects of development, and habitat-related issues as they pertain to development. UN agencies such as the United Nations Development Program (UNDP) have made a major contribution to intellectual endeavor in defining the parameters of development and their progress in several parts of the world through the publication of the *Human Development Report* series. Yet, despite all these efforts, and the enormous progress that has been made in sensitizing decision makers around the world to every aspect of human development, several interlinkages between population, environment, and development have not been fully understood thus far. Nor has the quantitative impact of one set of variables on the other in these three subjects been understood fully. The myths that governed thinking and official action at the time of Stockholm, and two decades earlier, have not yet been demolished. For instance, much of the world has been party to a paradigm of economic development that is based on growth in consumption of goods and services, which necessarily impacts on the environment, leading to increasing levels of use of natural resources. Imperfections in pricing and the exclusion of externalities in market signals has only led to far greater than optimal use of natural resources. Indeed, it would be correct to state that the very essence of human values has been distorted through excessive use of natural resources and consumptive life-styles. In this respect, perhaps little has changed since Stockholm.

The nonmaterialistic values in human existence have, as a result, been ignored by the human race, in what is often seen as a mindless pursuit of greater and greater consumption of goods and services and generating higher incomes by all possible means to enhance access to higher levels of consumption.

However, it is now becoming clear that the increasing environmental damage that our present patterns of development are imposing on the earth's ecosystem would actually lead to higher costs and increasing constraints on the production of goods and services. Environmental protection and mitigation of damage would face higher marginal costs, which would lead to diversion of incomes from consumption to environmental protection. Already, estimates of the gross domestic product diverted to the protection of the environment, and the costs imposed by environmental damage in different countries, range from anywhere between two to six per cent. Present levels of consumption and exploitation of natural resources would naturally push these figures higher. Undoubtedly, population increases and demographic changes are an important determinant of consumption and production levels. In the case of India, for instance, the population of the country was below 400 million at the time of Independence in 1947, and, at the end of the first 50 years, it would stand at around 950 million, which amounts to an increase of almost one and half times the original level. The increased demand for food and agricultural output with this increase puts enormous pressure on land under agriculture, with corresponding increases in the demand for fertilizers, pesticides, and irrigation, which alone can bring about higher yields in the face of limitations in the expansion of land under agriculture. Even more important than aggregate numbers is the mix of the population, their income levels, and differences in life-styles. The conclusion first expressed in Stockholm that poverty is the worst polluter holds true a quarter of a century later. In respect of a basic commodity like fuelwood, larger numbers of the poor naturally translates into greater felling of trees and cutting of branches and twigs, which are essential for the sustenance of the poor, who need basic fuels for cooking. These are very visible impacts, which are pointed out extensively in every forum. Far less visible and several orders of magnitude more damaging are the consumptive life-styles of the rich in the most prosperous societies of the world.

This volume contains contributions by some of the most enlightened researchers and thinkers of our time, who have done substantial work on the fundamental issues linking population, environment, and development. A volume of this nature cannot provide ultimate answers, but it can certainly help in framing the right questions. It is hoped that at the end of this set of writings, we would be in a position at least to articulate these questions, while, at the same time, seeing the broad contours of solutions. Policy makers, leaders of public opinion, and humanity, in general, need to develop these solutions urgently, to ensure a sound ecological base for supporting life on this planet in the 21st century and beyond.

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POPULATION AS A SCALE FACTOR: IMPACTS ON ENVIRONMENT AND DEVELOPMENT

Robert Engelman[1]

INTRODUCTION AND BACKGROUND: SCIENTIFIC UNCERTAINTY AND POLICY IMPLICATIONS

The rapid expansion of human activities in recent decades is the decisive factor in the present alteration of natural resource bases that have been available to societies for ages. Scholars and analysts have been unable to reach any agreement on the role population growth plays in this alteration. They differ substantially on the relative importance of simple human numbers on the one hand, and, on the other, the multiple aspects of human behavior, such as consumption patterns, political institutions, inequitable wealth distribution, and technological change (LeRoy 1995[2]).

In part, this confusion stems from a lack of uniformity in dealing with the critical issue of *time.* The population growth of any given time period may have little impact on the use of a natural resource *during the period of that growth.* Yet, the cumulative product of past growth may largely determine the scale of the resource use even after a population stabilizes. The current disproportionate share of the world's energy used by the US, for example, owes more to the three percent annual population growth that the country experienced in the 19th century, than to the one percent annual growth it experiences today. One can add as well, of course, that the average American uses many times more commercial energy than the average resident of most developing countries. However, this fact would be only of passing consequence had the US population stabilized at its 1820 size of 9.6 million (US Census Bureau 1994). By the same reasoning, the environmental impacts of today's population growth in rapidly growing countries may not be fully evident until after these populations have stabilized, presumably at a time when development has advanced and per capita consumption is higher than it is today.

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[2] This bibliography contains sections listing surveys of the literature, compilations, and theoretical and conceptual works.

For a variety of reasons – especially the complexities and uncertainties inherent in human and physical systems – a precise quantification of the role of population dynamics in natural resource use and disposal is not possible. The pursuit of precision in this field is valuable in that it improves understanding and stimulates dialogue. If the discussion brings policy makers to a greater appreciation of the importance of population dynamics in environmental preservation and sustainable human development, so much the better. Yet the reality is that many policy makers are becoming more convinced about the importance of population by the realities that they observe within their own countries – growing conflicts over scarce water supplies, for example, or food production that fails to keep up with increasing demand – than by abstract scientific analysis and debate. The intricacies of the relationships may elude them, but they know there is an intimate connection between the size and change of their populations and the resource problems which they must manage. Increasingly, it is the presidents, the agriculture ministers, the water planners, and the directors in the fisheries department who call attention to the unsustainability of their nations' population growth rates.

This reaction is an appropriate one. Despite the lack of scientific consensus on the nature of population impacts on the environment and prospects for development, the implications of the research for population policy are relatively straightforward. The ongoing growth of human population in most countries challenges efforts to improve human life and conserve the natural world on multiple fronts. The improvements that would have occurred in recent decades in food production and in the consumption of energy and water have been significantly undermined – and in some cases reversed – because population growth has worked in the opposite direction of the gains in per capita production and efficiency. This destructive pattern will be defused only when populations stabilize – or, more accurately, when population sizes alter only modestly and decline as much, and as often, as they increase.

If the most effective policies to slow population growth over the long term were expensive or onerous – if they violated human rights, for example – an airtight scientific argument would clearly be needed that population was the 'major cause' of environmental degradation. However, this is not the case, so there is no such need. As 179 nations agreed in Cairo at the 1994 International Conference on Population and Development, the very policies that most directly improve the well-being of individuals worldwide – especially the well-being of women – are the ones most effective in slowing population and eventually bringing nations to stable population sizes. Among these policies is universal and affordable access to safe and voluntary family planning and related reproductive health services, so that all couples and women can have the childbirths they want to have when they want to have them, and in good health. The importance of family planning is demonstrated in the evidence that desired family size is falling dramatically around the world, even in Africa, while access to a choice of affordable and effective contraceptive techniques is spreading far more slowly. By some estimates, universal access to family planning services would result in a reduction of average fertility in developing countries halfway from the current levels of about four children per woman to a 'replacement value' of about two children per woman. This total fertility rate, if maintained, would result in stable populations within two or three generations (Sinding 1992). How does one move all the way to replacement fertility? An all-out societal effort to afford women and girls as many opportunities as men and boys in schools, in employment, in business, in politics, and in society, as a whole, would almost certainly result in average global fertility rates of two children per woman, or fewer, as has occurred in most of the world's industrialized countries.

It is important to establish, from the outset, the interrelation between sound population policies and human development based on individual freedom. The misconception persists that scholars must prove, beyond doubt, that population growth is a major cause of environmental degradation and the slowing down of economic development. Hence, policy makers can justify difficult, controversial, and expensive policies intended to restrain rampaging population growth. The overwhelming body of evidence and the global dialogue that took place in Cairo in 1994 argue precisely the reverse: enlightened population policies offer an easily affordable 'no regrets' strategy that make sense even if population growth turned out to be a perpetually benign factor in environmental conservation and economic development. Indeed, given the long time periods needed to achieve stable populations, we can argue that coercion in population programs is not only unethical, it would not work, as couples and women will eventually rebel and thwart the efforts of demographically driven bureaucrats. Only a sincere and responsible solution to the real and expressed problems of those of childbearing age for birth spacing and family-size limitation can lead to the ongoing, long-term changes necessary for bringing world population growth to a gradual halt.

We can now begin to explore the difficult terrain of population dynamics and their impact on countries in the process of development.

THE CURRENT AND PROJECTED FUTURE STATE OF WORLD POPULATION

The planet is now home to 5.7 billion people having gained more since 1950 than it had in all of time to that point. By one estimate, 105 billion human beings have lived on earth to date, but for the vast majority of the tens of thousands of years that human beings have walked on earth, world population was in the low millions, not the low billions (Haub 1995).

Today, four-fifths of the world's population lives in developing countries. This paper will address primarily the most direct impacts of this population growth in the countries where the growth is occurring. Yet, even this attempt to define the discussion is complicated by the difficulty of distinguishing local from remote population–environment linkages. More than half of all the world's population growth, for example, is occurring in countries with tropical forests, such as Zaire, Brazil, Indonesia, the Philippines, Mexico, and the nations of Central America. Discussing the ultimate and proximate causes of the loss of forests in these countries illustrates the perils of overly narrow views of what population growth is and where it is occurring. Various assessments have assigned the dominant responsibility in loss of forest cover either to 'population growth' – usually defined as the growth of landless farmers on the perimeter of forests – or 'logging' or other commercial resource extraction, including the spread of cattle ranches.

All of these factors, are however, linked to population growth occurring somewhere – the local growth to the inhabitants of the countries where the forests are found; the logging and cattle ranching to increasing global demand for tropical woods and beef. This growth clearly relates both to population and economic growth worldwide. In the first case, we can speak broadly about the local impacts of local population growth. In the second, we must consider the more complex interactions between population growth and consumption patterns in far-flung foreign markets. Both have an impact on the tropical forests, but we need to be precise about the differences.

Three United Nations (UN) projections suggest that world population in 2025 will be as low as 7.6 billion, or as high as 9 billion, or at a medium figure of 8.3 billion (UN 1994a). These are *not*, however, predictions, but scenarios based on assumptions about future birth, death, and migration rates that may or may not be close to the reality. UN projections suggest future population size as far as 2150 (Figure 1), when human numbers could be either still growing rapidly (high projection), roughly stable (medium projection) at around 12 billion, or declining gradually (low projection) based on low global average fertility rates (UN 1992). These are, of course, global figures, and the impact within certain countries is far more dramatic. If we assume, inaccurately, that the medium UN projection is an 'expected', or a 'most likely' scenario, we must then consider it 'likely' or 'expected' that Ethiopia will be home to 194 million people in 2050 (nearly four times its current population) and Pakistan will have 381 million people (nearly three times its current population). The impact of such populations on local resource bases, many of which already show evidence of stress and potential collapse, strains the imagination. The point here is that population projections are, in the words of Joel E Cohen, 'conditional predictions' (Cohen 1995), dependent on a number of assumptions that or may not prove valid. One such assumption is that population size can never reach a point where negative ecological and developmen-

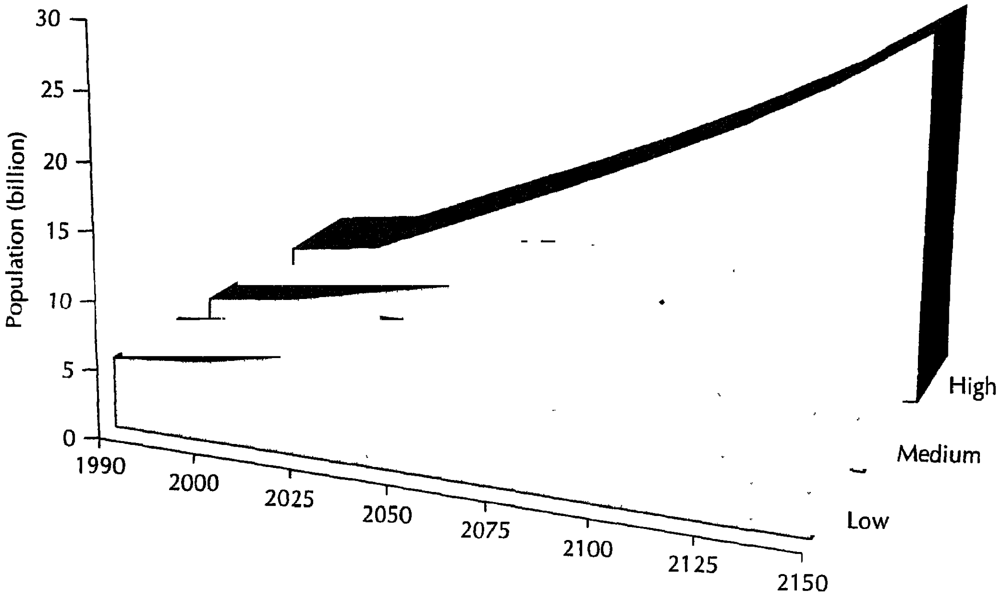

Figure 1. *World population (1990–2150): three projections*
Source. PAI (1996; based on data from the UN Population Division).

tal feedbacks would lead to increases in death rates. This assumption is clearly in error, but because no one is certain how to correct it, it remains fundamental to most population projections. For this reason and others,[3] population projections should be used with the understanding that they are mathematical constructs that can provide an idea, rather than any certainty, about how population growth will proceed in future decades.

One population trend with special importance to the environment and development prospects of less-industrialized nations is urbanization, the subject of a major UN conference in Istanbul later this year. More than half of the world's inhabitants are projected to be living in urban areas by the year 2005. In Latin America, this halfway point between countryside and city was reached years ago. Especially significant is the growing concentration of population in dozens of 'megacities' of 10 million or more (UN 1994b). This is a scale of urban agglomeration far beyond any the world has ever known.

At first glance, it may seem that urbanization will have environmental benefits by relieving population pressure in rapidly growing rural areas. However, this benefit is an illusion. Population growth continues in most rural areas, albeit usually more slowly than in nearby urban areas. City dwellers have needs for food, fuel, and materials that force the extension of supply networks into rural areas and even around the globe. As noted, the demands of wealthy urban dwellers for tropical woods and beef have contributed in past years to the destruction of rainforests. Moreover, the local environmental impacts of urban activities – air and water pollution, especially – can shorten human life and harm health. Since most megacities are on or near coasts, the world's population is also moving toward coastal areas, with inevitable impacts on fisheries and other coastal resources. Finally, the extreme and extended crowding that occurs in large, densely populated urban agglomerations adds substantially to the risk of outbreaks of infectious disease.

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[3] for a fuller discussion of the limitations of population projections see Engelman (1996: forthcoming).

Population momentum, resulting from the increase in young people now approaching or in their childbearing years, means that unless global catastrophe intervenes, world population will continue to grow for some time. The force of population momentum can be reduced somewhat by policies that successfully encourage later marriages and greater spacing of childbirths. However, unless birthrates reach an unexpected low, or death rates rise, or both, it is unrealistic to expect world population to stop growing before the year 2020.

Positive demographic trends include the growing desire for smaller families and personal regulation of fertility, and recent international consensus on the key elements of enlightened population policy. Both fertility and desired family size have been declining in most regions since the 1960s, and average fertility rates in developing countries have dropped from roughly six children per woman to fewer than four. More than half of all married couples in developing countries now use contraception, up from about 10% in 1960 (WHO 1992). This trend has recently become apparent even in some sub-Saharan countries, such as Kenya, Zimbabwe, Nigeria, and Botswana (Caldwell, Orubuloye, Caldwell 1992). As more people move to cities, seek education for their children, and encounter electronic media and the consumer culture, the desire for large families often weakens quickly.

From the standpoint of government policy, the Cairo conference offers real hope that population issues will be addressed in the future out of a shared commitment to human development and individual freedom to determine the timing of childbearing. The UN conference was historically unprecedented in achieving near international consensus for this strategy. The long-standing debate over the importance of contraception was resolved in favor of broad agreement that quality choices in family planning services should be universally available. So, too, should educational and economic opportunities that allow women to make informed, effective, and safe choices about when, with whom, and how often to bear children in good health.

Surprisingly, almost 45% of the world's people now live in countries in which average fertility rates have reached or fallen below 'replacement' – including almost all industrialized countries as well as China and some other developing countries in Asia. If fertility rates do not rebound significantly and if net immigration is not a significant demographic factor (as is the case in the

US, Canada, Australia, and, today, even Russia), the populations of these countries will stabilize by the middle of the next century – and may then begin to decline gradually.

Nonetheless, uneven access to family planning and reproductive health care services worldwide still condemns many couples and individuals to unintended pregnancy and childbearing. And, in the 18 months following the Cairo conference, it has become apparent that some countries are not prepared to honor their commitments made there. The US government, for example, has recently slashed funding for international population assistance, forcing developing countries in need of assistance to look elsewhere for leadership.

While we cannot predict precisely how much of a problem future human population growth will present for environment and development in developing countries, we *can* state confidently that the actions governments take today in the population arena will influence profoundly the size and date at which human population will stabilize in the next 150 years or beyond.

POPULATION-ENVIRONMENT INTERACTIONS

The existing population–environment research base tends to support the idea that human population itself – the number of human beings living in any unit of land – does not alter environments directly or in a linear fashion. Rather, population acts with and through such variables as social organization, government policy, dominant technology, and personal consumption behavior. The connections are complex, indirect, and variable by location and time scale. Often a rather long sequence of causation leads from population growth to changes in the environment, and this is true of the national impacts of national population dynamics.

In our work at Population Action International, we have found it useful to consider the changes in *per capita availability* of such key natural resources as renewable fresh water and arable land. Although these per capita figures are necessarily averages that do not reflect disparities in access to resources, they constitute an important first step in understanding population–natural resource linkages. Per capita availability establishes a background level of resource abundance or scarcity against which all politics, economics, and inequities in power and wealth play out. Moreover, per capita availability can be used as a kind of research 'control'. The concept helps analysts understand, where nations would be *absent,* the many factors that make for disparate access in real life. If societies ever approached the elimination of access inequalities and expanded *access* (the real capacity to use a resource) to the point that it approached *availability* (the theoretical capacity to use the resource), the per capita availability would indicate what each resident would have to work with.

Here again, it is useful to consider the growth of human *numbers*, not as a determinant of aggregate behavior, but as an expansion of the scale or field of activity in which real women, men, and children have real impacts on the environment. The scale of such activities and impacts tends to expand, while the scale of physical resources remains static or even declines. Being inventive, human beings typically develop new ways to use the resources more efficiently or imaginatively, but the scale imbalance – growing human activity against the backdrop of finite natural resource bases – remains. In the absence of *continuously successful* efforts to improve use efficiency or develop suitable substitutes for specific natural resources, population growth, thus, tends to push the scale of human activities to, and beyond, the points where collisions with natural resource limits occur.

THREE CRITICAL NATURAL RESOURCES: WATER, CROPLAND, AND FISH

This is anything but a theoretical formulation, as national and local policy makers the world over can attest. In country after country, wealthy as well as less wealthy, the supply of renewable fresh water is increasingly constraining the location and extent of settlement, agriculture, industry, and related development.

As renewable fresh water – that which is provided by the hydrological cycle as rain and snow falling on land – is finite, the amount of this water available to each person declines as population grows. Although renewable water must, and can, be used with much more efficiency, it is inevitable over the long term that population growth will result in increased human withdrawals from streams and rivers. At the point that a watershed becomes 'closed' – that is when all water is withdrawn, used, and 'consumed' (either through evaporation or severe pollution) – the entry of any new user requires that other users withdraw less than previously. This ongoing parcelization or subdivision of finite water supplies can be particularly hazardous in the many watersheds that cross country borders. Nine countries, for example, share the waters of the Nile River basin with Egypt, which sees the source of 97% of its fresh water threatened by the development efforts upstream. At the population levels that existed until the last few decades, almost no development scenario could have threatened Egypt's security. Under the population levels of the Nile basin projected for the 21st century, by contrast, any significant upstream development would reduce the flow of the Nile, every drop of which Egypt will need to produce its food, cool its industrial machinery, and keep its citizens healthy. This is a formula either for conflict or for energetic diplomacy, depending on the foresight of leaders in the Nile watershed.

Hydrologists use the benchmark of 1000 m^3 of renewable water per person per year as the upper boundary of water scarcity in a country, arguing that it is exceedingly difficult for a developing country to make the transition to full industrialization without this amount. A country may be able to base its development on nonrenewable water supplies (such as those offered by groundwater aquifers that filled naturally in the ancient past but are no longer recharged effectively under current climatic conditions). However, this is hazardous, as these aquifers eventually will become too depleted to use – perhaps at a time when both population and economic development have reached levels where the loss of dependable water supplies would threaten disaster. For the sustainability of societies, only renewable water should be depended upon, and its availability relates critically to population size and distribution.

We can quantify how many people are projected to live in countries with conditions of scarcity (with fewer than 1000 m^3 of water per person per year) or water stress (between 1000 and about 1700 m^3 per person per year). Data for both population and total annual renewable water is available for 149 countries. As can be seen in Figure 2, not only the number, but the proportion of people living in water-short countries will depend greatly on which trajectory of population growth the world follows in the coming century (Engelman, LeRoy 1993; 1995a). The UN 1994 medium population projection suggests that by the middle of the coming century, 4.4 billion of the nearly 10 billion people projected to inhabit the planet will live in 58 countries experiencing either water scarcity or water stress. Under the high projection, the proportion of the world's population living in 66 water-short nations would be 65% or 7.7 billion out of a total world population of 11.9 billion people. Under the low projection, by contrast, the proportion would be 44% or 3.5 billion people living in 51 water-short countries out of a total world population of 7.9 billion. Clearly, the extent of future water shortage will depend, to a large degree, on which trajectory population follows.

Mexico City offers a compelling example of the impact that growing water scarcity can have on urban environmental quality and development prospects. Less than 1000 years ago, the Aztec Indians settled on a verdant group of islands connecting two mountain lakes. Today the lakes have long since disappeared under pavements, and the megacity is home to more than 15 million people. About 70% of their water is supplied by underground aquifers, the ongoing depletion of which is causing the city to settle and sink, and is raising the risk of contamination by agricultural and industrial chemicals, which would be too expensive to clean up. Some water is drawn over mountain passes by pipelines, but this is expensive and few new sources of water are available as the population continues to grow in the regions surrounding Mexico City. The city could recycle its water more effectively, but apparently

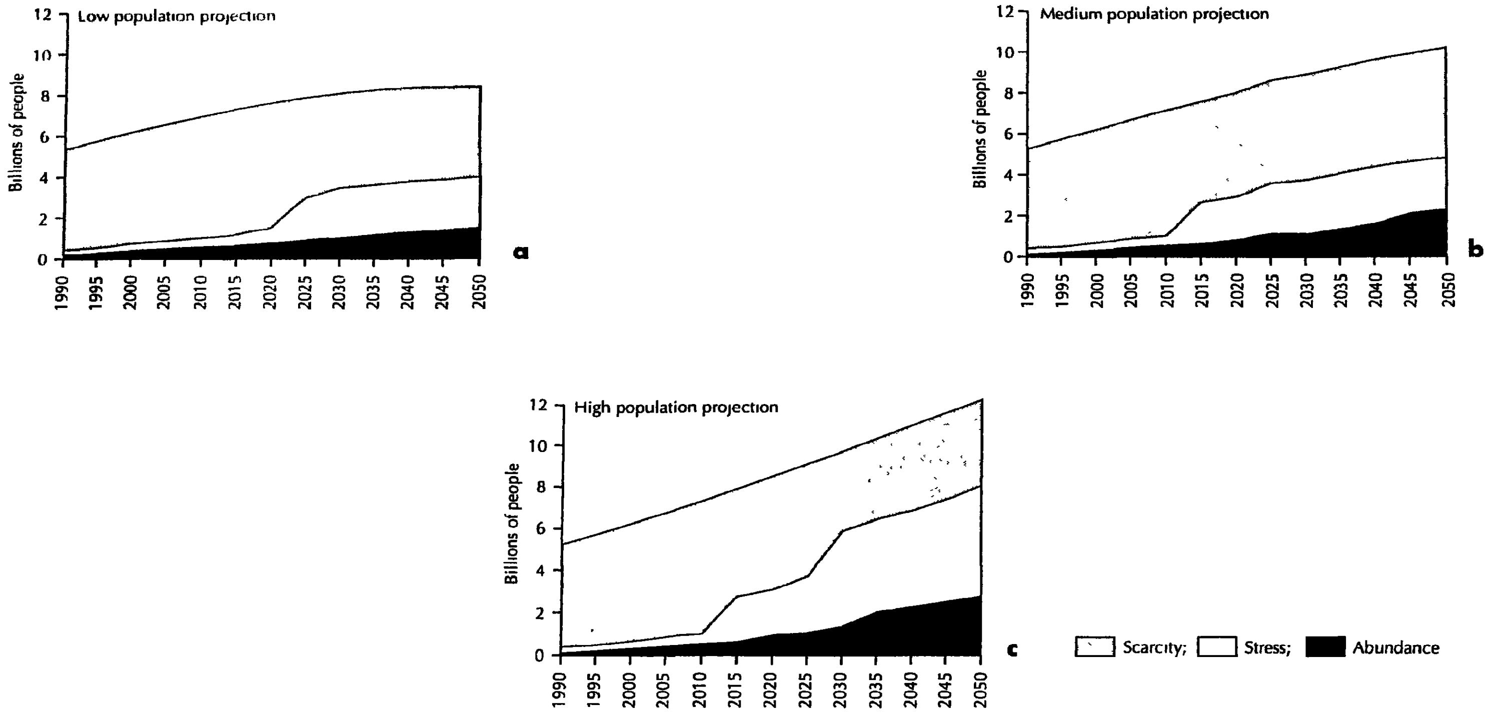

Figure 2. *Population experiencing fresh water scarcity (1990–2050);* **a** low population projection, **b** medium population projection; **c** high population projection
Source. PAI (1996).

has no long-term prospects for matching renewable water supply to the growing needs of its expanding populace (Nusser 1996).

A similar relationship between population growth and per capita resource availability applies to the use of farmlands, which most developing countries rely on domestically to produce the bulk of domestic food consumption. Unlike fresh water, food can be traded for in large quantities and transported over long distances. Yet, any country forced to rely on external sources of food must either produce some tradeable good at least as valuable as food (tourism, in the case of some small countries) or must depend on the whims of international charity for food aid. Policy makers in most developing nations prefer to base policy on the assumption of rough self-sufficiency in food after imports and exports are accounted for.

The global area of arable land has grown in rough correspondence with human population since the dawn of agriculture – until the past few decades, that is, when the expansion of arable land slowed down. World population now grows at eight times the pace of total area of arable land – 1.6% compared to 0.2% – which guarantees that the world's available arable land must be worked much more intensively to bridge the gap between the two rates (Engelman, LeRoy 1995b). As the agricultural frontier closes, land intensification is replacing land extensification.

Without special effort, this results in a depletion of soil-based carbon, which is the food on which a vast and diverse population of arthropods and microorganisms depends. There is very little research examining the dynamics of soil biodiversity, but there is increasing evidence that a wealth of species helps cycle essential nutrients – essential either to plant or human health, or both – between bedrock, soil, and atmosphere. Some microorganisms protect food plants from pathogens and disease (CISWRD 1991). Moreover, as monoculture expands in farming areas, both food-related and associated biodiversity decline, often necessitating greater use of chemical pesticides. Loss of nutrients, resulting not only from topsoil loss, but from the simple process of transporting crop material away from the soil on which it grows, requires increasing fertilizer use. This fertilizer will cost farmers money, and it may or may not make up for the ongoing loss of soil-based micronutrients. These may be critical not only for yield but for the health and disease resistance of the crop plant – not to mention the health and disease resistance of the human beings who ultimately consume the grains, fruits, and vegetables.

Arable land, like renewable water, is a finite natural resource. Thus, calculations, similar to those on water availability, can be made about the future of per capita arable land availability. No societies have managed to feed their populations with less than 0.07 hectares of arable land per person, unless they have used the kind of intensive, chemical-based agriculture common in Western Europe, Japan, and the American Midwest. Based on this benchmark, if we assume that global arable land extent will remain constant at 1990 levels (it is not expected to grow by much and could easily decline), the rate of population growth over the next 150 years will determine whether 1.6 billion people, 5.5 billion, or some number in between live in countries with scarcities of arable land in 2050 (Figure 3).

Obviously, technological innovation in agriculture has boosted yields in the past, and is likely to do so in the future. However, we cannot depend on the past as a guide. Farmers are stressing limited cropland as never before in history, and intensification must not only continue but accelerate to keep up with population growth, economic growth, and the drive to reduce malnutrition. Confidence that this task will be easy is unwarranted.

Most of the world's current population growth is occurring in countries – India, Pakistan, China, Mexico, and Ethiopia, for example – that have almost no potential for adding to farmlands. Indeed, these countries are actually losing cultivated land to the ubiquitous spread of factories, office buildings, shops, homes, and highways. The food that will be required to feed a world population of 8 billion or more in the next century will have to come almost entirely from today's farmlands. Yet, much of that farmland is not only shrinking in area, but is drying up, taking on salt and toxic metals, or losing topsoil and the nutrients on which plant and human health depend. An area of land the size of China and India has lost productive potential, while 25 billion tons of topsoil wash off the land each year. With farmlands, as with renewable fresh water, sound population policies are not an alternative but a supplement to the many steps needed to put resource use on a sustainable basis. Only when the demand for food is roughly stable, will the need to achieve food security and the need to conserve soil and water cease to be, to some extent, at odds.

The state of the world's fisheries provides similar evidence of a collision of human needs and natural resources that is occurring today. By the accounts of experts, the world's oceans and rivers are unlikely to be able to supply more than 60 million metric tons per year of fish as food for human consumption. This is actually slightly above levels at which the global fish catch has leveled off since about 1989. Aquaculture, growing rapidly, contributes roughly another 16 million tons today, and is likely to contribute more in the future. But how much more? Calculations by the PAI, based on UN population projections and the assumption of constant global per capita consumption of fish as food, indicate that by the middle of the next century, fish farmers would need to produce more food from fish than all that the world's oceans and rivers now contribute from wild-caught fish under both the medium and high population projections. Only under the low population projection would wild-caught fish still dominate, with aquaculture contributing 'only' 43 million tons of food (Figure 4). Most fish experts are skeptical that aquaculture can go much beyond twice its current outputs, if that, because of limitations on, and competition for, suitable land for ponds and pens and dependable water supply, and the growing challenge of keeping cultured fish in a state of reasonable health (Engelman, LeRoy 1995c).

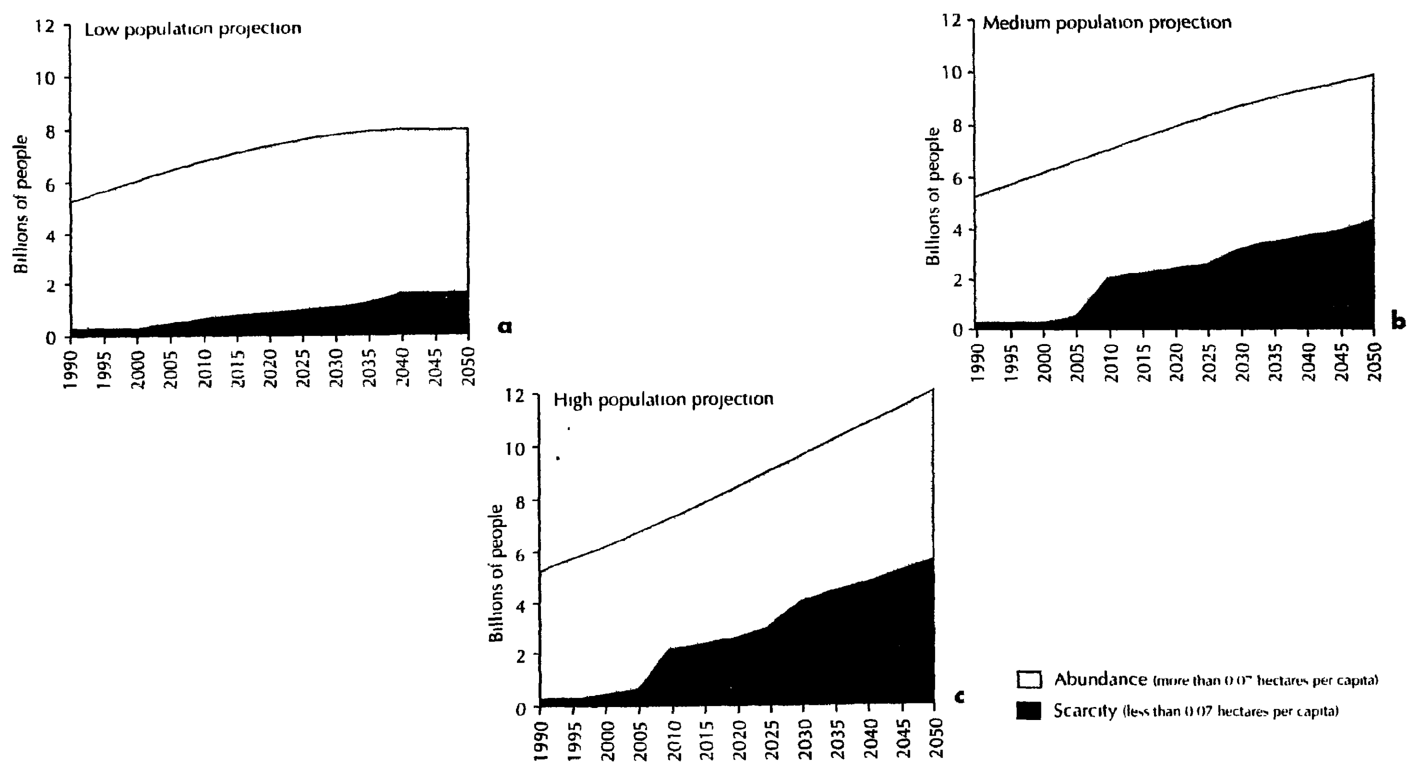

Figure 3. *World population and arable land availability (1990–2050): three projections;* ***a*** *low population projection;* ***b*** *medium population projection;* ***c*** *high population projection*

Note. The speed of population growth largely determines the number of people living in countries with less than 0.07 hectares per person of arable land, a benchmark of land scarcity. In 2050, the number of people living with arable land scarcity could range from 1.6 billion under the UN's low population projection to 5.5 billion people under the high projection.

Source. PAI (1996).

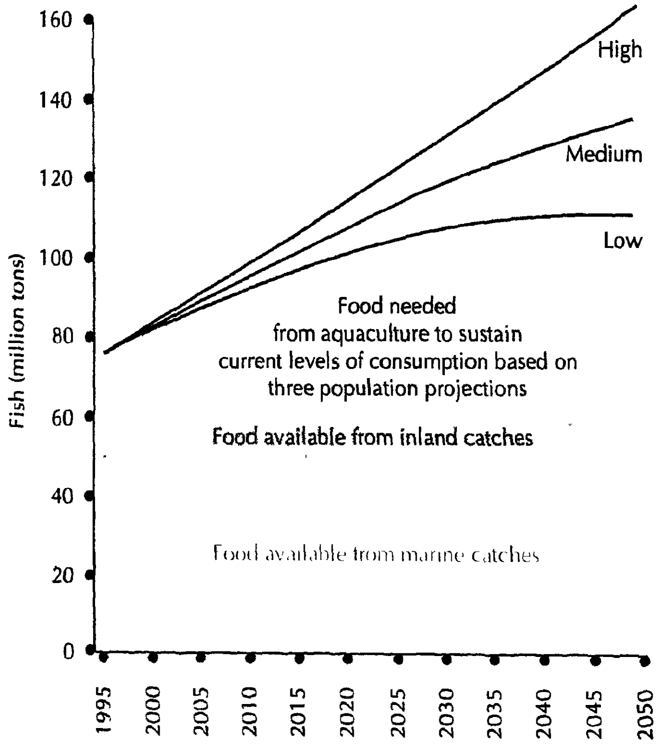

Figure 4. *Food from fish (1995–2050)*
Source. PAI (1996).

The implications of this calculation for the people of developing countries are sobering. Until populations stabilize, the cost of fish is very likely to continue to rise, pricing the poor out of what historically has been among the few inexpensive sources of high-quality animal protein. Stabilizing population alone would not reverse the decline of fisheries, but as with other critical natural resources that are vulnerable to growing human demand, a combination of population and conservation strategies will be needed to allow fish to once again become a nutritious food that is available and affordable to all.

THE CONVERGENCE OF THE NORTH AND THE SOUTH

Water, croplands, and fisheries are three of the most obvious examples of critical natural resources placed at risk, once certain natural thresholds are approached or crossed by national and local population growth. Although it is characteristic of both demographic and economic disciplines to separate the world's nations into two or three major groups, one cannot study these resources without being struck by the convergence of population-related resource problems in both the wealthier countries (the 'North') and those in the process of development (the 'South'). Water shortages and hazardous declines in water quality are experienced in many or most countries. Farmlands suffer soil erosion and nutrient loss and are converted to other uses in almost all countries. Fisheries are declining worldwide.

The long-repeated idea that environmental damage worldwide is caused predominantly by the wealthiest one billion people in the world and the poorest one billion is an oversimplification of the reality. All people, at all levels of incomes, have environmental impacts which vary by income level as well as by cultural, technological, and even individual human differences. The dramatic increase in the middle class within developing countries and the progress of globalized trade and globalized culture demonstrate the wide range of stresses large populations of all income levels have on local environments and governments' capacities to manage environmental change, while trying to encourage economic and social development. The immense problems Mexico City faces with air pollution, for example, demonstrate the complexity of linkages of population, consumption, and the environment. Is this a population problem? A consumption problem? A technological or a policy problem? A problem related to wealth or to poverty? It is all these and much more – as are most environmental problems with which policy makers must deal.

Perhaps the most difficult of these problems is the emerging challenge of stabilizing the planet's atmosphere. The scientific consensus has clarified in the past few months that humanity is not only raising the atmosphere's capacity to trap solar heat near the surface of the earth, but that this increased capacity is almost certainly contributing to climate change that is occurring today. This raises fundamental questions of international governance and equity. The nations and individuals who are contributing the most to the accumulating risk of human-induced climate change are precisely those who are most capable of adapting to the impacts of that change. Those nations and individuals contributing the least to the buildup of greenhouse gases in the atmosphere, by contrast, tend to have the least capacity for dealing with the predicted impacts of increased drought, increased flooding, sea-level rise, and alterations in patterns of infectious diseases. In the middle are a broad range of countries that contribute modestly to climate change and have some capacity to deal with the problems it may cause.

Clearly, the climate problem is global, and the solutions will need to be global as well. Equally clearly, population growth in wealthy as well as less wealthy countries is complicating the challenge of finding equitable ways to scale back the use of fossil fuels and other natural resources that contribute to the buildup of carbon dioxide and greenhouse gases. From the standpoint of equity, those countries that are 'climate sustainable' (not, on a per capita basis, contributing more greenhouse gases to the atmosphere than can be absorbed by the natural recycling of these gases) have a right to argue that they deserve assistance – indeed compensation – from those countries that are contributing to the growing risk of hazardous, human-induced climate change.

Yet, it is also the case that every country has a stake in encouraging population stabilization in all countries, since all human beings logically have an equal right to use the atmosphere for the disposal of greenhouse gases resulting from the activities of daily life. The higher the world's population climbs after nations become serious about stabilizing atmospheric concentrations of greenhouse gases, the smaller the allowable per capita emissions of such gases, and the more the pressure that will be exerted on individual atmospheric disposal rights. One could argue, as some have, that it will be up to the world's wealthy countries to resolve climate issues. However, world population could reach a point, under some projections, where even 'survival emissions' in a world without wealthy countries would be sufficient to elevate concentrations of greenhouse gases and augment climate change. For a more detailed discussion of this complex issue, see Engelman (1994).

RESPONSIBILITY AND THE CAPACITY TO RESPOND

As the examples of population–environment linkages indicate, once key natural thresholds are approached or crossed, population growth tends to limit the possibilities for effective response to resource scarcity. Governments are often forced into 'lose-lose' policy choices because no available option can quickly restore a natural resource base or environmental condition to its previous state – not, certainly, without trampling on legitimate interests. Ultimately, the need for near-miraculous policy solutions to natural resource constraints on development will be reduced, and the effects of good policies and programs can only be enduring if population itself is addressed as a critical factor within a matrix of other critical factors.

Fortunately, policy makers have already reached a global consensus on the kinds of policies that are the most effective and the most essential to slow the growth of world population. The representatives of national governments who attended the Cairo conference on population stressed the basic human right to regulate one's own reproduction. The Cairo agreement recognized that these services enabling couples, and especially women, to do this in good health should be voluntary and should offer a range of safe and effective contraceptive options. And they should be available and affordable to all who need them. Where possible, they should be provided in the context of services that include a broader range of maternal and child health care as well as reproductive health care services.

Distressingly, the US government recently decided to abandon leadership in working with developing nations on the provision of critical family planning and reproductive health services. As a result of efforts by some in the US

Congress to equate family planning and contraception with abortion, the money the US will spend on international assistance in this area will be only 14% – literally less than one-seventh – as much in fiscal year 1996 as was spent in 1995. Moreover, no US money can be committed to family planning programs abroad until after 1 July. The effects of this reversal are likely to be disruptive and, possibly, shattering to the health of women of childbearing age and their children, and it can only harm efforts to slow population growth in developing countries based on the childbearing desires of women and couples. For at least the foreseeable future, it will require political will among other population program donors and the governments and nongovernmental sectors of developing countries themselves to continue and expand the work already begun to achieve universal access to quality, voluntary family planning services.

The survival of children also contributes, over the long term, to an easing of population growth rates, despite the fact that the initial influence may, for obvious reasons, be in the direction of higher population growth. There are two important aspects, however, beyond the obvious ethical ones, of enabling infants and children to survive till their own reproductive years. One is that when first and second pregnancies are successful and children survive their early years, parents are much less likely to insist on multiple pregnancies beyond the number of children they ultimately want in their families. The other aspect is that one of the most important health interventions in aiding child survival is the use of contraceptives, which enables women to delay births beyond adolescence and then to space births by at least two years. By attenuating each woman's reproduction (and men's, too, on average), postponement of, first, childbearing, and then, the spacing of subsequent pregnancies can have an impressive impact on birth and population growth rates – as well as on the health and lives of women and children – even if they had no impact on fertility (Bongaarts 1994). This adds to the arguments for universal access to voluntary family planning services.

As the Cairo conferees also agreed, it is critical to provide girls and young women with at least the same schooling that boys and young men receive. Educated young women are far less likely than uneducated adolescents to become pregnant, less likely to have large families, and more likely to use contraception. Moreover, they are more likely to make a contribution to their societies and economies beyond that of motherhood. Ultimately, the synergistic effect of access to family planning, education, and economic opportunities is so powerful that it is quite likely that something like the UN's low population projection could be achieved if all three could be provided to all the world's women. The low population trajectory would be the product, not of successful 'population control' or of global demographic targets, but of the collective actions of hundreds of millions of men and women with the capacity to make and put into effect their own decisions about childbearing.

The effect of such policies – while immediate in the lives of women, couples, and communities – will be modest in the near term in slowing population growth within most developing countries. Over several decades, however, the impact of sound population policies will help determine the development prospects for nations on all the major continents. The stabilization of human population size will mark the dawn of an era in which problems of environmental conservation and economic development no longer pull governments in conflicting directions or accelerate toward disaster even as societies work to resolve them.

Population policies centered on human development and individual freedom would merit support even if they had no impact on population growth rates, because they improve well-being in multiple ways that have nothing to do with demographic change. Such policies are all the more urgent because of the close interdependence among human population dynamics and the integrity of natural resources critical to prosperity, health, and survival itself.

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HOW MANY PEOPLE CAN THE EARTH SUPPORT?[1]

Joel E Cohen[2]

ESTIMATES OF HUMAN CARRYING CAPACITY

On 25 April 1679, in Delft, Holland, the inventor of the microscope, Antoni van Leeuwenhoek, wrote down what may be the first estimate of the maximum number of people that the earth can support. If all the habitable land in the world had the same population density as Holland (at that time about 120 people for every square kilometer), he calculated that the earth could support at most 13.4 billion people – far fewer than the number of spermatozoans his lenses had revealed in the milt of a cod.

In subsequent centuries, van Leeuwenhoek's estimate has been followed by dozens of similar calculations. Around 1695, a Londoner named Gregory King estimated that the earth's 'land if fully peopled would sustain', at most, 12.5 billion people. In 1765, a German regimental pastor, Johann Peter Süssmilch, compared his own figure (13.9 billion) with the estimates of van Leeuwenhoek, the French military engineer, Sébastien le Prestre de Vauban (5.5 billion), and the English writer and cartographer Thomas Templeman (11.5 billion).

In recent decades, estimates of maximum population have appeared thicker and faster than ever before. Under the rubric of 'carrying capacity', they crop up routinely in environmental debates, in United Nations (UN) reports, and in papers by scholars or academic politicians trained in ecology, economics, sociology, geography, soil science, or agronomy, among other disciplines. Demographers, however, have been strangely silent. Of the more than 200 symposiums held at the 1992 and 1993 annual meetings of the Population Association of America, not one session dealt with estimating or defining human carrying capacity for any region of the earth. Instead, professional demographers tend to focus on the composition and growth of populations, restricting their predictions to the near term – generally a few decades into the future – and framing them in conditional terms: *If* rates of birth, death,

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and migration (by age, sex, location, marital status, and so on) are such-and-such, *then* population size and distribution will be so-and-so.

Such conditional predictions, or forecasts, can be powerful tools. Projections by the UN showed dramatically that *if* human populations continued to grow at 1990 rates in each major region of the world, *then* the population would increase more than 130-fold in 160 years, from about 5.3 billion in 1990 to about 694 billion in 2150. Those figures are extremely sensitive to the future level of average fertility. If, hypothetically, from 1990 onwards the average couple gradually approached a level of fertility just one-tenth of a child more than required to replace themselves, world population would grow from 5.3 billion in 1990 to 12.5 billion in 2050 and 20.8 billion in 2150. In contrast, if (again hypothetically) starting in 1990, and ever after, couples bore exactly the number of children needed to replace themselves, world population would grow from 5.3 billion in 1990 to 7.7 billion in 2050 and would level off around 8.4 billion by 2150.

The clear message is that people cannot forever continue to have, on average, more children than are required to replace themselves. That is not an ideological slogan; it is a hard fact. Conventional agriculture cannot grow enough food for 694 billion people; not enough water falls from the skies. The finiteness of the earth guarantees that ceilings on human numbers do exist.

Where are those ceilings? Some people believe that any limit to human numbers is so remote that its existence is irrelevant to present concerns. Others declare that the human population has already exceeded what the earth can support in the long run (how long is usually left unspecified). Still others concede that short-term limits may exist, but they argue that technologies, institutions, and values will adapt in unpredictable ways to push ceilings progressively higher so that they recede forever. The differences of opinion are buttressed by vast disparities in calculation. In the past century, experts of various stripes have made estimates of human carrying capacity ranging from less than a billion to more than 1000 billion. Who, if anyone, is right?

For several years, I have been trying to understand the question – How many people can the earth support? – and the answers to it. This question cannot be answered by a number or even by a range of numbers. The earth's capacity to support people is determined partly by processes that the social and natural sciences have yet to understand, and partly by choices that we and our descendants have yet to make.

NATURAL CONSTRAINTS AND HUMAN CHOICES

In most of its various scientific uses, *carrying capacity* refers to a population of wild animals within a particular ecosystem. One widely used ecology textbook defines it as follows

> *Number of individuals in a population that the resources of a habitat can support; the asymptote, or plateau, of the logistic and other sigmoid equations for population growth.*

Even within ecology, the concept of carrying capacity has important limitations. It applies best under stable conditions and over relatively short spans of time. In the real world, climates and habitats fluctuate and change; animals adapt to their conditions and eventually evolve into new species. With each change, the carrying capacity changes as well.

When applied to human beings, the concept becomes vastly more volatile. I have collected 26 definitions of human carrying capacity, all published since 1975. Most of them agree on a few basic points – for instance, that the concept refers to the number of people who can be supported for some period (usually not stated) in some mode of life considered plausible or desirable. Most of the definitions recognize that ecological concepts of carrying capacity must be extended to allow for the role of technology. Most also agree that culturally and individually variable standards of living, including standards of environmental quality, set limits on population size well before the physical requirements for sheer subsistence start to become an issue.

In other respects, however, the definitions vary widely or even contradict one another. How long must a population be sustainable? Does it make sense to speak of local or regional carrying capacity – or do trade and the need for inputs from outside any specified region imply that only a global scale will do? Or, a more fundamental question – how constraining are constraints? Some definitions deny the existence of any finite carrying capacity altogether, holding that human ingenuity will win out over any natural barriers; others acknowledge that the limits are real but recognize that human choices, now and in the future, will largely decide where those limits fall.

In my opinion, that last point – the interplay of natural constraints and human choices – is the key to making sense of human carrying capacity. The deceptively simple question – How many people can the earth support? – hides a host of thorny issues.

HOW MANY PEOPLE AT WHAT AVERAGE LEVEL OF MATERIAL WELL-BEING?

The human carrying capacity of the earth will obviously depend on the typical material level at which people choose to live. Material well-being includes food (people choose variety and palatability, beyond the constraints imposed by physiological requirements); fiber (people choose cotton, wool, or synthetic fibers for clothing, wood pulp or rag for paper); water (tap water or Perrier or the nearest river or mud hole for drinking, washing, cooking, and watering your lawn, if you have one); housing (Auschwitz barracks: two men to a plank; or Thomas Jefferson's Monticello); manufactured goods; waste removal (for human, agricultural, and industrial wastes); natural hazard protection (against floods, storms, volcanoes, and earthquakes); health (prevention, cure, and care); and the entire range of amenities such as education, travel, social groups, solitude, the arts, religion, and communion with nature. Not all of those features are captured well by standard economic measures.

HOW MANY WITH WHAT DISTRIBUTION OF MATERIAL WELL-BEING?

An ecologist, an economist, and a statistician went bow hunting in the woods and spied a deer. The ecologist shot first, and his arrow landed five meters to the left of the deer. The economist shot next, and her arrow landed five meters to the right of the deer. The statistician looked at both arrows, looked at the deer, and jumped up and down shouting: 'We got it! We got it!'

Estimates of human carrying capacity rarely take into account the distribution of material well-being throughout a population. Yet, paying attention to average well-being while ignoring the distribution of well-being is like using an average arrow to kill a deer. People who live in extreme poverty may not know or care if the global average is satisfactory, and the press of present needs may keep them from taking a long-term view. For example, thanks to genetic engineering, any country with a few PhDs in molecular plant biology and a modestly equipped laboratory can insert the genes needed to create stronger, more disease-resistant, higher-yielding plants. If every region has the scientific and technical resources to improve its own crop plants, the earth can support more people than it can if some regions are too poor to help themselves.

HOW MANY PEOPLE WITH WHAT TECHNOLOGY?

The complexities of technological choices often disappear in heated exchanges between environmental pessimists and technological optimists. Ecologists argue that when a natural resource is being consumed faster than it is being replenished or recycled, an asset is being depleted, to the potential harm of future generations. However, technologists assert that if new knowledge and technology can produce an equivalent or superior alternative, then future generations may turn out to be better off. Taxpayers, in turn, tend to raise questions such as: which are the natural resources that can be replaced by technology yet to be invented, and which cannot? Will there be enough time to develop new technology and put it to work on the required scale? Could we avoid future problems, pain, and suffering by making other choices now about technology or ways of living? Neither the ecologist nor the technologist has any answers to these questions.

The key to the argument is time. As Richard E Benedick, an officer of the US Department of State who has also served with the World Wide Fund for Nature, worried (Benedick 1991)

> *While it is true that technology has generally been able to come up with solutions to human dilemmas, there is no guarantee that ingenuity will always rise to the task. Policy makers must contend with a nagging thought: 'what if it does not, or what if it is too late?'*

HOW MANY PEOPLE WITH WHAT DOMESTIC AND INTERNATIONAL POLITICAL INSTITUTIONS?

Political organization and effectiveness affect human carrying capacity. For example, the United Nations Development Program estimated that developing countries could mobilize, for development, as much as $50 billion a year (an amount comparable to all official development assistance), if they reduced military expenditures, privatized public enterprises, eliminated corruption, made development priorities economically more rational, and improved national governance. Conversely, population size, distribution, and composition affect political organization and effectiveness.

How will political institutions and civic participation evolve with increasing population? As numbers increase, what will happen to people's ability to participate effectively in the political system? What standards of personal liberty will people choose?

How will people bring about political change within existing nations? By elections and referendums, or by revolutions, insurrection, or civil war? How will people choose to settle differences between nations, for instance, over disputed borders, shared water resources, or common fisheries? Wars consume human and physical resources. Negotiations consume patience and often require compromise. The two options impose different constraints on human carrying capacity.

HOW MANY PEOPLE WITH WHAT DOMESTIC AND INTERNATIONAL ECONOMIC ARRANGEMENTS?

What levels of physical and human capital are assumed? Tractors, lathes, computers, better health, and better education – all these resources make workers in rich countries far more productive than those in poor countries. Wealthier workers are more productive and can support more people.

What regional and international trade in finished goods and mobility in productive assets are to be permitted or encouraged? How will work be organized? The invention of the factory organized production to minimize idleness in the use of labor, tools, and machines. What new ways of organizing work should be assumed to estimate the future human carrying capacity?

HOW MANY PEOPLE WITH WHAT DOMESTIC AND INTERNATIONAL DEMOGRAPHIC ARRANGEMENTS?

Almost every aspect of demography (birth, death, age structure, migration, marriage, and family structure) is subject to human choices that will influence the earth's human carrying capacity.

A stationary global population will have to choose between a long average length of life and a high birth rate. It must also choose between a single average birth rate for all regions (some areas have fertility above their replacement level, whereas other areas have fertility below their replacement level), on the one hand, and a demographic specialization of labor, on the other.

Patterns of marriage and household formation will also influence human carrying capacity. For example, the public resources that have to be devoted to the care of the young and the aged depend on the roles played by families. In China, national law requires families to care for and support their elderly members; in the US, elderly people often rely on their own resources and those of the state.

HOW MANY PEOPLE IN WHAT PHYSICAL, CHEMICAL, AND BIOLOGICAL ENVIRONMENTS?

What physical, chemical, and biological environments will people choose for themselves and for their children? Much of the heat in the public argument over current environmental problems arises because the consequences of present and projected choices and changes are uncertain. Will global warming cause great problems, or would a global limitation on fossil fuel consumption cause greater problems? Will toxic or nuclear wastes or ordinary sewage sludge dumped in the deep ocean come back to haunt future generations when deep currents well up in biologically productive offshore zones, or would the long-term effects of disposing of those wastes on land be worse? The choice of particular alternatives could materially affect human carrying capacity.

HOW MANY PEOPLE WITH WHAT VARIABILITY OR STABILITY?

How many people the earth can support depends also on how steadily you want the earth to support that population. If you are willing to let the human population rise and fall, depending on annual crops, decadal weather patterns, and long-term shifts in climate, the average population with ups and downs would include the peaks of population size, whereas the guaranteed level would have to be adjusted to the level of the lowest valley. Similar reasoning applies to variability or stability in the level of well-being; the quality of the physical, chemical, and biological environments; and various other dimensions of choice.

HOW MANY PEOPLE WITH WHAT RISK OR ROBUSTNESS?

How many people the earth can support depends on the desired controllability of the well-being of the population. One possible strategy would be to maximize numbers at some given level of well-being, ignoring the risk of natural or human disaster. Another would be to accept a smaller population size in return for increased control over random events. For example, if you settle in a previously uninhabited hazardous zone (such as the flood plains of the Mississippi River or the hurricane-prone coast of the southeastern US), you demand a higher carrying capacity of the hazardous zone; you must, however, accept a higher risk of catastrophe. When farmers do not give fields a fallow period, they extract a higher carrying capacity along with a higher risk that the soil will lose its fertility (as agronomists at the International Rice Research Institute in the Philippines discovered to their surprise).

HOW MANY PEOPLE FOR HOW LONG?

Human carrying capacity depends strongly on the time horizon that people choose for planning. The population that the earth can support at a given level of well-being for 20 years may differ substantially from the population that can be supported for 100 or 1000 years.

The time horizon is crucial in energy analysis. How fast oil stocks are being consumed matters little if one cares only about the next five years. In the long term, technology can change the definition of resources, converting what was useless rock to a valuable resource; hence, no one can say whether industrial society is sustainable for 500 years.

Some definitions of human carrying capacity refer to the size of a population that can be supported indefinitely. Such definitions are operationally meaningless. There is no way of knowing what human population size can be supported indefinitely (other than zero population, since the sun is expected to burn out in a few billion years, and the human species almost certainly will be extinct long before then). The concept of indefinite sustainability is a phantasm, a diversion from the difficult problems of today and the coming century.

HOW MANY PEOPLE WITH WHAT FASHIONS, TASTES, AND VALUES?

What people want from life also determines the number of people the earth can support. Many choices that appear to be economic depend heavily on individual and cultural values. Should industrial societies use the available supplies of fossil fuels in households for heating and for personal transportation, or outside of households to produce other goods and services? Do people prefer a high average wage and low employment or a low average wage and high employment (if they must choose)?

Should industrial economies now seek to develop renewable energy sources, or should they keep burning fossil fuels and leave the transition to future generations? Should women (and men) work outside their homes? Should economic analyses continue to discount future income and costs, or should they strive to even the balance between the people now living and their unborn descendants?

I am frequently asked whether organized religion, particularly Roman Catholicism, is a serious obstacle to the decline of fertility. Certainly, in some countries, church policies have hindered couples' access to contraception and have posed obstacles to family planning programs. In practice, however, factors other than religion seem to be decisive in setting average levels of fertility for Roman Catholics. In 1992, two Catholic countries, Spain and Italy, had the second- and third-lowest fertility rates in the world. In largely Catholic Latin America, fertility has been falling rapidly, with modern contraceptive methods playing a major role. In most of the US, the fertility of Catholics has gradually converged with that of Protestants, and polls show that nearly four-fifths of the Catholics think that couples should make up their own minds about family planning and abortion.

Even within the church hierarchy, Catholicism shelters a diversity of views. On 15 June 1994, the Italian Bishops' conference issued a report stating that falling mortality and improved medical care 'have made it unthinkable to sustain indefinitely a birthrate that notably exceeds the level of two children per couple'. Moreover, by promoting literacy for adults, education for children, and the survival of infants in developing countries, the church has helped bring about some of the social preconditions essential for fertility decline.

On the whole, the evidence seems, to me, to support the view of the ecologist William W Murdoch of the University of California, Santa Barbara (Murdoch 1991)

> *Religious beliefs have only small, although sometimes significant, effects on family size. Even these effects tend to disappear with rising levels of well-being and education.*

IMPROVING THE ART OF LIVING

In short, the question – How many people can the earth support? – has no single numerical answer, now or ever. Human choices about the earth's human carrying capacity are constrained by facts of nature and may have unpredictable consequences. Consequently, estimates of human carrying capacity cannot aspire to be more than conditional and probable: if future choices are thus-and-so, then the human carrying capacity is likely to be so-and-so. They cannot predict the constraints or possibilities that lie in the future; their true worth may lie in their role as a goad to conscience and a guide to action in the here and now.

The following beautiful quotation, by the English philosopher John Stuart Mill (Mill 1848) sketches the kind of shift in values such action might entail. When it was written in 1848, the world's population was less than one-fifth its present size.

> *There is room in the world, no doubt, and even in old countries, for a great increase of population, supposing the arts of life to go on improving, and capital to increase. But even if innocuous, I confess I see very little reason for desiring it. The density of population necessary to enable mankind to obtain, in the greatest degree, all the advantages both of cooperation and of social intercourse, has, in all the most populous countries, been obtained. A population may be too crowded, though all be amply supplied with food and raiment. It is not good for man to be kept perforce at all times in the presence of his species. A world from which solitude is extirpated, is a very poor ideal...Nor is there much satisfaction in contemplating the world with nothing left to the spontaneous activity of nature; with every rood of land brought into cultivation, which is capable of growing food for human beings; every flowery waste or natural pasture ploughed up, all quadrupeds or birds which are not domesticated for man's use exterminated as his rivals for food, every hedgerow or superfluous tree rooted out, and scarcely a place left where a wild shrub or flower could grow without being eradicated as a weed in the name of improved agriculture. If the earth must lose that great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger but not a better or a happier population, I sincerely hope, for the sake of posterity, that they will content to be stationary, long before necessity compels them to it.*
>
> *It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture,*

> *and moral and social progress; as much room for improving the Art of Living, and much more likelihood of its being improved, when minds ceased to be engrossed by the art of getting on. Even the industrial arts might be as earnestly and as successfully cultivated, with this sole difference, that instead of serving no purpose but the increase of wealth, industrial improvements would produce their legitimate effect, that of abridging labor...Only when, in addition to just institutions, the increase of mankind shall be under the deliberate guidance of judicious foresight, can the conquests made from the powers of nature by the intellect and energy of scientific discoverers, become the common property of the species, and the means of improving it and elevating the universal lot.*

NOTE

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POPULATION, ENVIRONMENT, AND DEVELOPMENT: INTERACTIONS AND ISSUES

Paris William Reidhead, Lubina F Qureshy, Vishal Narain[1]

INTRODUCTION

Past development efforts have laid emphasis primarily on attaining high rates of economic growth with little regard for sustainability. In recent decades, the urbanization and industrialization associated with this growth, coupled with a rapidly growing population, have had grave impacts on the environment and on the stock of natural resources. With the realization that these past patterns have not been conducive to sustainable development, the focus has now shifted towards attaining a balance between population size, available resources, and the capability of the economy to provide basic needs within the limits imposed by the biosphere.

The World Commission for Environment and Development brought to the fore the concept of sustainable development in the 1987 report, *Our Common Future.* The Commission emphasized that present generations should

> *...meet their needs without compromising the ability of future generations to meet their own needs...Development cannot subsist upon a deteriora-ting environmental base; the environment cannot be protected when growth leaves out of account the costs of environmental destruction. These problems can not be treated separately by fragmented institutions and policies. They are linked in a complex system of cause and effect* (WCED 1989).

Herman Daly (1993) views sustainability in terms of *scale,* i.e., the size of the economy in relation to the ecosystem. The economic system, being a physical subset of the natural ecosystem, cannot grow beyond the scale of the

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[1] Tata Energy Research Institute, Darbari Seth Block, Habitat Place, Lodhi Road, New Delhi - 110 003, India.

latter, and undue emphasis on growth tends to push it beyond what is sustainable. Or, in other words, in their effort to maintain their present scale of per capita consumption, many countries are consuming their natural capital and counting it as income. Thus, the most critical question is how to achieve sustainable development given the constraints imposed by population and the environment.

THE WORLD DEMOGRAPHIC PICTURE

The world population currently stands at 5.8 billion. This number is expected to exceed 6 billion by the turn of the century, and to reach nearly 8.5 billion by 2025. Table 1 shows total population over time, with its regional distribution. Between 1950 and 1995, world population grew at a rate of 1.9% per annum, compared with 0.9% in the half century preceding 1950. As much as 83% of this increase was seen in the southern developing countries. Asia, excluding Japan, has the largest share of the world population – 57% of the total – which is concentrated primarily in China and India. Africa is currently experiencing the highest rate of growth of population at three percent per annum.

What separates the experience of the now-developed countries from that of their developing counterparts is that the former enjoyed high rates of industrial growth concomitant with their growth of population. Thus, an in-

Table 1. *World population trends from 1900–2100*

Region	*1900*[a]	*1950*	*1995*	*2000*[a]	*2025*	*2100*[a]
Developing world						
Africa	133	222	744	872	1583	2591
Asia	867	1294	3281	3419	4773	4919
Latin America	70	148	447	546	651	1238
Subtotal	1070	1664	4472	4837	7007	8748
Industrial world						
Europe, Japan, Oceania, and (former) Soviet Union	478	656	931	987	1012	1055
North America	82	166	292	297	360	382
Subtotal	560	822	1223	1284	1372	1437
World	1630	2516	5759	6121	8472	10185

[a] From Pearce, Warford (1993)
Source WRI (1994)

crease in numbers in these countries did not pose a constraint to the development process. As a result of this complementarity, the developed countries of the North experienced a slow secular trend in population growth; and the relative availability of economic resources provided some incentive for more stable fertility rates. The natural population growth rate did not exceed two percent per annum. However, developing countries have shown very high rates in their early stages of development (more than 2.5% per annum), stemming largely from advances in medical science and reductions in mortality from disease. This decline in mortality rates in the face of relatively high fertility rates, paired with the frequent lack of industrialization, implies that developing countries will have difficulty in emulating the path taken by the now-developed countries of the world.

THE POPULATION-ENVIRONMENT-DEVELOPMENT LINKAGE

Reproduction, particularly in developing countries, can be viewed as a microeconomic decision. Each child born confers benefits to the family, not only in terms of personal happiness, but also in terms of labor productivity and old age security. The costs associated with a child include food, clothing, and shelter (which have direct impacts on the family), but may also include government welfare, resource depletion, and waste generation, which are borne by society as a whole. It is the failure to account for these external costs in personal reproductive decision-making which leads to excess population, and it is these same costs that cause population to be seen as a societal problem.

The impact of population size on natural resources becomes significant when a growing population increasingly impinges on a resource base that is inelastic in supply (Mink 1993). This implies a diminished per capita availability of resources and a negative impact on living standards. The impact on the environment is often viewed in terms of the concept of carrying capacity. Ehrlich, Holdren (1974) define carrying capacity as

> *...the maximum number of individuals that can be supported by a given habitat; it is usually related to the availability of a limiting resource, one that is in short supply in relation to a population's needs.*

According to this definition, if nothing else changes, increasing populations will ultimately put demands on resources, and these demands will not be met without adverse effects on the ability of the natural environment to support the human populace. Carrying capacity cannot, however, be considered in the abstract. The ability of the land to support human population can be complicated additionally by factors such as trade, consumption magnitude and technology (Ramakrishnan 1994).

THE RELATIONSHIP QUANTIFIED

In an attempt to quantify the relationship between population, environment, consumption, and technology, Ehrlich and Holdren formulated the following simple identity

$I = P \times A \times T$

where I represents the impact of population on the environment, P represents population size, A represents the level of affluence or per capita consumption of a resource, and T represents the environmental damage caused by the technology used in attaining that level of affluence.

The above equation does not take into account the vulnerability of the environment, or the cultural, economic, and institutional aspects of consumption and technology. However, it does show that environmental degradation can be caused by any of the three factors, by themselves, or in combination with the others. In cases where more than one of the factors increases simultaneously, there is an additional synergistic effect.

The relationship is complicated further by the interactions among the three right-hand-side factors (IIASA 1994). For example, insofar as population growth can lead to increased unemployment and shortages of food, it will be associated with a decrease in per capita consumption. Similarly, others argue that the same demographic growth will act to spur the evolution of adaptive technology (Boserup 1965). And yet others point out that affluence increases the opportunity cost of children and would thus lead to a decrease in population. In short, there is a very intricate web of factors that is at play in the population–environment–development debate: demographic, technological, ecological, economic, and cultural – all of which can have a positive or negative effect on the others. Thus, a search for a cause is largely ineffectual.

Focusing on population and the environment, we can see examples of these complexities (Mink 1993). Demographic pressure in rural areas has been linked to growth in fuelwood collection and the associated deforestation. As collection time increases, it becomes desirable for a family to have additional help in the form of children. Thus, fertility remains high or increases. This is an example of a positive feedback between environment and fertility. However, negative feedbacks exist as well. Population-induced agricultural land degradation can necessitate male urban migration, and the resultant spousal separation has been correlated to fertility decline in rural areas (Qutub 1992).

Whether demographic changes will lead to the degradation of the environment and whether such degradation will have positive or negative feedback effects depend largely on the specific context of the situation. For example, Bilsborrow, Okoth-Ogendo (1992) discuss four ways in which rural agricultural systems can respond to demographic pressure, namely, through changes in land ownership and classification (*tenunal*), increases in area of land cultivated (*extensification*), modification of agricultural practices (*technological* or *intensification*), and reductions in fertility and delays in marriage (*demographic*). Any or all of these phases may occur, and each has its own implications for the environment and resource base. The context, namely the influence of institutional and political as well as natural factors, determines which of these is experienced.

Another example of the intricacies of context is provided by Taylor, Garcia-Barrios (1996). They refer to two hypothetical countries, both experiencing a rapid doubling of population. One country encounters environmental degradation and poverty almost immediately, while the other requires several generations before it suffers any of the same effects. The only difference between the two is the initial land distribution. It is as such that other factors can exacerbate the already complicated relationship between population and the environment.

ISSUES RELATED TO THE IMPACTS OF POPULATION AND DEVELOPMENT

Although it is difficult to establish causality when dealing with the impacts of demographic change, it is often useful to examine environmental impacts in terms of several issues that are largely associated with population growth.

POVERTY AND ENVIRONMENT

Population seldom has direct impacts on the environment. The environmental impacts attributed to population occur as responses to poverty, and, therefore, it is in its role as a contributing factor to poverty that population becomes an important environmental causative force.

Due to their economic status, the poor often have no choice but to inhabit marginal areas that are environmentally vulnerable and also lacking in modern infrastructure, and may not have the means to counteract the adverse impacts of environmental degradation. Perhaps the most serious form of environmental pollution to which they are exposed is water pollution. The lack of adequate sanitation and access to safe drinking water is responsible for the incidence of diseases such as gastroenteritis, diarrhoea, and cholera. The poor are also exposed to health hazards due to indoor air pollution arising from the use of cheap biomass fuels such as wood, crop residues, and dung.

Those attempting to make a living on marginal lands frequently have deleterious impacts on those lands as well. Unsustainable intensive agricultural practices such as monocropping and shifting cultivation with short or no fallow periods can lead to nutrient depletion and salinization, and deforestation and farming on hill areas cause soil and wind erosion and flooding, not to mention losses in biodiversity.

Such degradation adversely affects the health of the poor and their capacity to work. They are made to divert a large proportion of their time to routine tasks such as the collection of fuelwood and water, which has associated high opportunity costs in terms of alternate sources of income. Moreover, the declines in the productivity due to illness and degraded resources further depress their ability to generate income.

The degradation can be explained in terms of discount rates. Due to their circumstances, many poor place a very high time value on money, and those who would normally desire long planning horizons are unable to act accordingly (Mink 1993). As a result of such high discount rates, the poor have no incentives to invest in environmentally sustainable practices, and are often forced to consume their resources, rather than utilizing them wisely as investments for the future. In addition to their financial plight, the poor's high time value of money is reinforced by an unusually large burden of risk. Their welfare is highly vulnerable to political instability, weather and natural disasters, and problems of health. This risk contributes to their short-sightedness. To make matters worse, environmental degradation itself adds to the abundance of risk faced by the poor.

There is a distinction between the type of environmental degradation associated with poverty and that associated with other causes, that is, a distinction between the effects of subsistence *versus* the effects of commercial consumption. The impacts described above are mostly local in nature and their effects are largely confined to the poor themselves. However, other types of degradation, e.g., outdoor air pollution, ozone depletion, acid rain, and nonrenewable resource exhaustion, can all be attributed to increases in consumption. This point is a subtle one, and its importance becomes clearer when speaking of policies.

Ironically, developmental activities also can have adverse impacts on the poor. For example, the construction of dams, though essential for the economy, tends to dislocate the population residing in those areas, as well as to cause the destruction of forests and biodiversity. Since the poor are heavily dependent on natural resources for their subsistence, such dislocation would, in turn, impose an additional burden on them. Furthermore, Arrhenius (1992) points out that growth in global electric power consumption will be associated with worldwide economic development and could lead to an 80% increase in carbon dioxide emissions. It is feared that these emissions would be tied to a rise in sea level, which could have a disproportionate impact on the developing countries (Mahtab, Karim 1992).

URBANIZATION AND MIGRATION

A demographic trend that is of great concern for the future is urbanization. By the year 2015, 56% of the global population is expected to live in urban areas, compared to 45% in 1994. Furthermore, most of this increase is likely to be concentrated in the developing countries, where the level of urbanization is expected to rise to almost 50% from the present level of 26%.

The rate at which urbanization is taking place in the developing world is not different from that experienced by the nondeveloped countries. However, two distinguishing features are the size of the developing country cities and the pace at which they are growing. European cities achieved a maximum rate of growth of 2.6% in the late 1800s, and, as mentioned above, this growth was accompanied by industrialization. Strikingly, in developing countries, the rate of urban growth is a rapid 4.1% (Mink 1993). Furthermore, at the start of their present modernization phase, these countries have also had large shortfalls between their industrial growth and population increase rates.

Rural-to-urban migration plays an important role in the growth of cities. Migration is usually a response to imbalances between rural population levels and the capacity of local resources to support that population. Whereas it was previously believed that migration to cities was a simple function of these population levels, the belief now is that population is only an indirect factor, and that economic prospects, land tenure, and agricultural productivity (which are all influenced by population) are the direct causes (Qutub 1992).

The impacts of rural-to-urban migration are mixed in nature. On one hand, the rapid growth of population in urban centers has resulted in the widespread proliferation of slums and inequitable patterns of consumption and access to resources. The increase of population densities in urban centers tends to place greater demands on urban infrastructure, particularly the provision of water and sanitation. This has implications for equitable economic development, since vast numbers of persons residing in slums and squatter settlements lack access to basic infrastructure. Furthermore, high urban population densities can overload the natural ability of the urban environment to assimilate the wastes and emissions from human activities, thus increasingly exposing residents to various health hazards.

On the other hand, urban areas often make more efficient use of space than their rural counterparts, and generally benefit from infrastructural scale economies, from the substitution of abundant resources for scarce ones, and from a reduction in impacts on open natural areas (Qutub 1992). Demographically, urban areas have also seen a relative reduction in fertility (as compared to rural areas) resulting from better job security and educational opportunities (Pearce, Warford 1993).

Rural-to-rural (or circular) movement is a second category of migratory response. This type of migration is largely associated with agricultural land extensification, but may be caused by some of the same factors as rural-to-urban movements. One obvious benefit of migration from rural areas experiencing demographic and economic pressures is the reduction of impacts on the local environment in these areas (Mink 1993). However, many of the lands to which people are migrating are marginal and require slightly different agricultural practices, and thus are environmentally vulnerable to the new inhabitants (Mink 1993). Another cost of such relocation is the social psychological disruption that occurs when a significant portion of a town or village leaves its ancestral home (Taylor, Garcia-Barrios 1996). Many resource conservation practices depend on local social institutions, which may be undermined by rural outmigration.

FOOD SECURITY

Food security was defined at the 1974 World Food Conference as 'physical and economic access to food to all people at all times' (Swaminathan 1993).

In most developing countries, these norms are not met and chronic hunger prevails. However, this situation is more a problem of distribution than one of aggregate supply, and the theory propounded nearly 200 years ago by Thomas Malthus, that population growth would outstrip food production, has not been supported in reality. The past two centuries have provided ample evidence of the benefits of technological innovation. Between 1960 and 1990, the Green Revolution led to a tripling of food production in developing countries, as well as a fall in the proportion of malnourished, from 36 to 20% (Swaminathan 1993).

As a measure of the carrying capacity of the earth, scientists have attempted to estimate the total production of the earth's land if it were completely dedicated to food production. The UN Food and Agriculture Organization (FAO) found that, at intermediate levels of technology, the total biological potential of the planet is four times the projected population for 2000 (Pearce, Warford 1993). While this seems promising, the authors warn that allowing for the production of nonfood crops (e.g., cotton, tobacco, etc.), at lower levels of technology, the world's capacity falls to only 1.07 times the 2000 population. Furthermore, the model assumes a subsistence standard of living and does not allow for increases in nutritional status. Clearly, there is a need for continued agricultural growth in the face of the expected increase in population.

Apart from the issue of hunger and malnutrition, it is necessary to consider the question of long-term resource constraints, which have been overlooked in the pursuit of attaining higher levels of agricultural production. The architect of the Green Revolution, Norman Borlaug, had warned that agricultural advances would be of a temporary nature; we have already begun to experience diminishing returns. This decade has seen a decrease in the growth of world grain production, from a 1990 harvest of 1.78 billion tons of grain to 1.69 billion tons in 1995, corresponding to a record low carry-over stock of 49 days of consumption (Brown 1996). In addition, the use of fertilizers, pesticides, and high-yield crop varieties as well as the expansion of irrigated land has not been without cost. The intensive utilization of fertilizers and hazardous chemicals to keep ahead of pest evolution contributes to both surface and ground water pollution; overuse of land for cultivation and grazing has contributed to accelerated erosion and desertification in many regions; and it is estimated that 14 million additional tons of global grain output is lost each year due to land degradation and crop damage (Mink 1993).

A rise in the demand for food, largely due to an increase in population, imposes a demand for bringing in more land under cultivation. In an econometric study of Latin American countries, Southgate (1990; cited in Mink 1993), inferred that as population growth rates increased, these countries experienced an expansion in agricultural area. This growth in agricultural land area is also likely to place greater pressure on biodiversity, mainly through deforestation.

Thus, although modern agriculture has been able to meet the demands for food by a growing population, these past experiences should not provide grounds for complacency. At the same time, it must be emphasized that even though there has been progress in agricultural production, chronic hunger still persists in many parts of the world. The problem of equitable distribution has not been addressed with the seriousness it deserves, as the recent cases of famines in parts of Africa have shown. Thus, food security entails eliminating chronic hunger and starvation while arresting the degradation of environmental capital stocks so as to enable sustainable agricultural production.

CONSUMPTION AND THE NORTH-SOUTH DEBATE

A point of much contention between the North and South is whether poverty or affluence contributes more to environmental problems. As has been seen in developing countries, the subsistence needs of an impoverished population are the driving force for natural resource depletion. Furthermore, poverty itself may be a prominent, if not the chief, incentive for a large family. In these countries, children are engaged from a young age in the tasks of collecting fuel, fodder, and timber for the household. In that sense, they are 'productive assets' for the family. And as the population of developing countries continues to grow, they make an ever-increasing contribution to total world consumption.

On the other hand, despite lower levels of population, developed countries consume far more resources per capita than their developing counterparts, thereby multiplying the strain on natural resources. For example, one American is estimated to consume the same amount of energy as 14 Chinese and 38 Indians (Goodland 1994). According to 1990 World Energy Council estimates, North America consumed 7.82 tons of oil equivalent (toe) of primary energy per capita. In contrast, Western Europe consumed 3.22 toe of primary energy per capita, the Commonwealth of Independent States, 5.01, and Central and Eastern Europe, 2.91. These figures were vastly lower for sub-Saharan Africa at 0.53 toe per capita and for South Asia at 0.39.

The disparities in consumption levels are not limited to petroleum products. Table 2 makes comparisons between developing and developed countries for several natural resources and products. In almost every case, the industrialized regions consume a full order of magnitude more than their developing counterparts. The table shows that the largest differences lie in metals and fossil fuels, which is consistent with the gaps in industrial production between the two regions.

Although the majority of consumption-driven degradation is experienced by the consuming countries themselves, e.g., soil erosion in developing countries and automobile emissions in industrialized countries, there are indirect effects from the flow of materials through trade. For example, about two-thirds of the agricultural and industrial raw material exports from developing countries are to industrial countries (WRI 1994). Thus. the demand for production inputs by the North may indirectly contribute to environmental degradation in the South.

However, it is at the global level where most of the debate lies. The North argues that developing countries contribute a significant share to damaging the global environment. Although, on a per capita basis they emit less than one-quarter the amount of greenhouse gases as the North, on an aggregate scale their levels are more similar (Boydon, Dovers 1992). And, as population

Table 2. *Comparative resource consumption (1986–1990)*

Resource	*Industrialized countries*	*Developing countries*
Fossil fuels (GJ/capita)	160.06	17.28
Aluminum (mt/100 capita)	14.13	0.69
Copper (mt/1000 capita)	8.06	0.48
Roundwood (m^3/capita)	1.29	0.48
Beef and veal (kg/capita)	27.17	4.29
Cotton (kg/capita)	5.35	2.69

Source WRI (1994).

expands, the demand for nonrenewable resources such as coal, oil, and metal ores is expected to rise. Furthermore, as demonstrated in Table 3, when their living standards improve and consumption per capita grows, their contribution will become increasingly significant. The North thus seeks that the South curtail its environment-damaging activities, while the South seeks the right to follow the same resource-intensive path to development enjoyed by the North. This argument has been observed within the implementation of the Montreal Protocol as well as in the current discussion of global climate change.

As compelling as the issue of the global commons is to the North–South debate, we must not overlook the distinction made earlier between the environmental effects of commercial consumption *versus* those of subsistence. Developing countries may or may not be correct in their belief that Northern consumption (i.e., consumption related to both population and living standards) is responsible for much of the degradation of the global environment. However, trying to allocate the blame in this manner may not be the best solution for the problems that they are facing. The issues that are of direct concern to the South, namely soil and water degradation, food availability, and urban conditions, result from their own magnitude of numbers and the struggle of a large fraction of their inhabitants to achieve even a subsistence level of consumption. This is not to say that Northern countries do not have a duty to assist their Southern brethren in mitigating these problems. It is to say that Southern problems must be addressed via Southern solutions.

Table 3. *Population growth and energy consumption by region: 1960–1990*

Region	*Percentage of increased energy consumption due to increase in population*	*Percentage of increased energy consumption due to rise in living standards*	*Energy consumption per capita 1960 (billion joules)*	*Energy consumption per capita 1990 (billion joules)*
Africa	32	68	6	13
Asia	16	84	8	24
Europe	17	83	72	126
North America	90	10	—	—
Canada	—	—	164	301
United States	—	—	236	292
South America	39	61	16	29
World	46	54	38	57

Source. Adapted from Pearce, Warford (1993); 1990 data from UNEP (1994).

POLICY SUGGESTIONS

As the relationship between population, environment, and development is such a complex one, policy recommendations must encompass several perspectives, at the macro or national level, and at the micro or local level, as well as between Northern and Southern countries. Policy suggestions are divided into four conceptual areas. The first two areas address the relationship described in the Ehrlich equation at the macro level, and the second two suggestions will apply to the micro level.

MACRO-LEVEL POLICIES FOR NORTHERN COUNTRIES

Although this paper has downplayed the importance of nonrenewable resource depletion and global climate change as environmental problems, they are certainly of import to the world in the long run, and the developing world will contribute to their evolution. Furthermore, as long as we do not have the option of leaving the planet, the plight of the citizens of Southern countries will not escape those of the North, if for no other reason than the poverty-induced political instability in petroleum exporting countries. Therefore, it is in the long-term interest of the North to turn its attention to bring about solutions to the problems that we have discussed.

Northern countries do not have a population problem in the usual sense, i.e., they are not suffering from widespread poverty and massive local environmental degradation. However, they do have a very large effective population. Therefore, although the rate of population growth in the US is currently of the order of one percent per year (World Bank 1994), in light of its per capita consumption, there are significant implications for world resource use. This is consistent with the Ehrlich equation. A look at the mathematics reveals us that in a country with a high per capita consumption and low population, a marginal increase in population has a larger effect on the environment than does a similar increase in consumption. Therefore, even a modest slowing of US population growth would certainly contribute towards a reduction in the scale of throughput. Achieving zero (or negative) population growth in Northern countries should hopefully be easier than in developing countries, since there already exists high levels of literacy, and children do not play as large an economic role in the family.

Even if they focus on population growth, Northern countries should not neglect their levels of per capita consumption. The levels of consumption in these countries are unsustainable in that they lead to global environmental problems and that a large portion of the resources consumed originate in Southern countries. A reduction in consumption can, in fact, be advantageous to these countries if they are achieved by increases in efficiency. Goodland (1994) lists ways in which developed countries can save money by modifying certain aspects of their economies, e.g., increasing mass transportation, encouraging energy conservation through domestic heating efficiency, and shifting from capital-intensive to service industries.

Northern countries should go one step beyond modifying their own behavior and take active steps in assisting Southern countries in their quest for population stability and environmental sustainability. In addition to international development aid, it is critical that the North be generous with its intellectual property. Since the environment is an indivisible global good, Northern technologies must be regarded as international public goods. Global arrangements should, therefore, recognize this and include mechanisms to subsidize the acquisition of these technologies by developing countries that neither have the expertise nor the finances to invest in research and development. This argument also applies to technological know-how in areas concerning other basic needs – food, health, pharmaceuticals, housing, and education.

MACRO-LEVEL POLICIES FOR SOUTHERN COUNTRIES

In keeping with the Ehrlich relationship, countries with high population and low levels of consumption should focus on their increasing levels of consumption. While few people would suggest that the South abandons its ambitions of raising its living standards, it is possible to improve the quality of life without increasing levels of consumption more than necessary. In some ways, this goal may prove easier to achieve in the South than in the North, since it means, in many cases, only adding efficient social and technological systems, rather than replacing old ones. In this instance, the South would do well to adopt renewable energy systems rather than ones based on fossil fuel, and labor-intensive industries rather than capital-intensive ones. It should be emphasized that the South is not to be restricted from increasing its consumption. In many ways, affluence is tied to living standards, and often they cannot be separated.

The South, of course, must also enact effective population policies. Macroeconomic growth is necessary to eliminate poverty, to decrease private discount rates in the long term, and to ensure that population stabilization is permanent. However, in the short run, far-reaching socioeconomic and political changes are necessary to reduce birth rates to replacement levels. Historical evidence suggests that when individuals and families gain power because their rights are protected, particularly the rights to education, medical care (including contraception), old-age security, and access to income-producing resources, they no longer have to depend on their own families for survival (Lappe, Schurman 1989).

As made clear at the 1994 International Conference on Population and Development in Cairo, ensuring the success of family planning programs requires complementary measures for raising the social, economic, and political status of women. At the same time, it is necessary to promote cost-effective health care measures to secure further reductions in infant mortality rates (UN 1994). This would ease the survival insecurity in families, which compels them to have as many children as possible as a cushion against a high rate of child mortality. Family planning services must be made available universally at an affordable cost and with a particular stress on maternal health. In addition, all these activities have to be integrated, in turn, with efforts targeted at poverty alleviation. Any population policy, especially in a large country like India, should also take account of regional variations in socioeconomic parameters.

Past population policies in developing countries have been guided by the view that the primary obstacle to reducing fertility is inadequate access to, or the prohibitive costs of, contraceptives. Therefore, their efforts have been directed at removing these constraints. It is now accepted that making family planning available is not sufficient unless there is a demand for its use. The measures suggested should act to increase the desire for limiting family size. However, there is already a significant portion, approximately 20%, of childbearing age couples who have unmet needs for family planning. Meeting this need would require only $11 billion annually (Mink 1993), and would enable world population to be stabilized at about 10 billion persons. This figure is 2.5 billion lower than the base case projection and would cost only about $10 annually for each person in the developed world.

BREAKING THE LINKS BETWEEN POPULATION AND ENVIRONMENT

Population growth is not a problem in itself. It is only the impacts of an ever-expanding population on a finite natural environment and the impacts of the same degradation on fertility that cause concern. Short of finding an infinite supply of resources, the best way to address the population–environment problem is to break the link between the two. While we work at the long-range solution of social and economic change, we can achieve more immediate relief by stopping the vicious feedback cycles between increased fertility and degradation.

Prevent environmental degradation from increasing fertility

When faced with the adversity of poverty and damage to their resource base, the poor find themselves with little control over their welfare. It is in these situations that they may turn to their seemingly only economic option: increasing their family capital by adding to its size. It would be beneficial then to construct policy measures that deflect this desire to have children as a result of adversity. Insofar as children serve as factors of household production, providing alternatives to poor households in the form of clean water and cheap fuel would preclude the need for children for menial household tasks like collecting firewood, dung, and water. A second reason for having children is for the old age insurance that they provide. If localities could provide ready access to credit and capital, it would increase the economic security for the poor in their old age and diminish the value of children as a form of insurance (Dasgupta 1992).

Arrest the degradation of the environment from demographic pressure

Many types of environmental degradation are at least partly a result of demographic factors, i.e., when the over populous poor are confronted with hunger and an apparently hopeless future, they revert to consuming their natural capital. Thus, it would be valuable to identify solutions that would give the poor additional options.

Means to mitigate environmental degradation can be separated into two broad categories: incentives and institutions. Residents of developing countries often lack incentives for conservation, or worse, encounter incentives that encourage actions that are damaging to the environment. Local and central governments need to remove subsidies that encourage the rapid removal of groundwater, the clearing of forests for agricultural land and commercial timber, and the overuse of fertilizers and pesticides. They need to invest in infrastructure that facilitates access to both clean drinking water and to land appropriate for farming. Further, they should create property rights for the efficient use of resources and provide both formal and informal credit to help spread out risks. Lastly, they should stand ready with emergency aid in times of floods, droughts, and other natural disasters.

In order to promote equality and efficiency and to provide assistance to the poor in the face of survival pressures, developing countries need to create new institutions. These might include a legal and judicial framework that settles land ownership disputes and enforces tenure systems. They might also include agricultural extension offices for the dissemination of information about agricultural and conservation practices; cooperatives for agricultural market power and risk sharing; schools for educating villagers about resource management; and hospitals to mitigate some of the public health impacts caused by existing pollution. Finally, as Boserup emphasizes, a large population should not be overlooked as a human resource. Labor must be allowed to reorganize, and the Taylorian 'labor surplus' must be eliminated.

The above policy recommendations do not address the larger social and economic factors that lead to the problems that we have examined. However, until those concerns can be taken care of independently, these measures will break the downward spiral between fertility and degradation and prevent further impacts on the lives of those in developing countries.

RESEARCH AGENDA

In addition to the above issues, there should be a conscious research agenda that addresses the points outlined below.

- *The conflict between environmental considerations and development strategies.* There is significant uncertainty as to the degree to which these are mutually exclusive. What is needed is an investigation of the factors that facilitate/impede the coevolution of environmental protection and development. As with the discussion below of sub-Saharan Africa and Korea (see Annexures I and II), the relationship may be best revealed through country and regional case studies which are location-specific.
- *Identifying means for changing consumption patterns in the North as well as in those 'Northern' regions that exist within Southern countries.*
  As environmental problems are often global in nature, all such research should ideally be conducted as a joint effort between developing and developed countries.
- *Determining which is the limiting factor of development – environment or human capital.*
  Since, in many cases, developing country governments lack the financial resources to simultaneously undertake policies that address both the natural and the human resource base, studies on this theme would give countries an indication of where best to focus their efforts. This also should be approached through country and regional case studies.
- *Impact of industrialization on the rural poor.*
  It is often assumed that development activities have universal positive welfare effects. However, every development activity does have its negative aspects, and all such undertakings require research in the form of environmental impact assessments that look at the effects of industrialization on the social, economic, and environmental systems in those areas.
- *Urbanization and its impact on the urban poor.*
  Although, cities provide amenities unavailable in rural areas, the poor in urban areas often experience little improvement in access to such infrastructure and services. It is necessary to make a critical examination of the status of the urban poor to see where gains can be best made in terms of preventing harm to the urban environment as well as mitigating the effects of environmental pollution on them.
- *Evolution and development of environmentally friendly technology adapted to the poor.*
  Although the Green Revolution may be three decades old, there is still much potential for technological advances that enable the poor to make more out of their limited resources and to subsist in ways that have minimal adverse impacts on both themselves and the environment.

- *Training modules for scientists, policy makers, and nongovernmental organizations.* These training efforts will aim to facilitate technological innovations, as well as their adoption, adaptation, and management. In the end, all population and development policies will be implemented by individuals at the grassroots level. It is thus necessary to find the most effective way to utilize these individuals in achieving the desired ends, and to adopt policies that advance such programs.

ANNEXURE I

THE CASE OF SUB-SAHARAN AFRICA[2]

The interface between demographic forces, development, and the natural resource base is perhaps well brought out in the case of sub-Saharan Africa. Looking at sub-Saharan Africa, we see how the demographic processes of high population growth, urbanization, and migration have transformed the pace of development and have had deep implications for future food security and the deterioration of the environmental resource base.

The African demographic explosion is characterized by a growth rate of three percent per annum, resulting in a doubling of population every 20 to 30 years. Almost half the total population in sub-Saharan Africa is below the age of 16. This imbalance of the age structure in rural areas is reinforced by the migration of young men in their 20s, leaving behind villages with a large majority of children. In addition to 'natural' population growth, sub-Saharan Africa contains about 35 million international migrants, of which around 4 million are refugees.

Not only is Africa the world's fastest growing region in terms of population, it is also the poorest. The average income per capita in 1992 was $530 with a negative growth rate of eight percent during 1980–1992. The poor of the region rely on the surrounding natural resource base and follow short-term survival strategies; the consequent degradation of the resource base lowers productivity and increases the poor's vulnerability to environmental disaster and ill-health.

Urbanization is rapidly transforming the nature of African development. 30 years ago, there was only one city with a population of more than 1 million; in 1990 there were 18. African cities have not been able to develop the basic environmental services to accommodate this addition of urban dwellers, which has resulted in a steady deterioration of the urban environment, particularly affecting the poor. Moreover, most of the urban population tends to be concentrated in the coastal zones, so that these areas experience a multitude of problems related to agriculture and fisheries, water management and infrastructure, and urban and industrial development. Most governments do not have institutional mechanisms to deal with these complex issues.

In the next three decades, population growth, migration, and resettlement are expected to change the face of sub-Saharan Africa. By 2025, the population of sub-Saharan Africa is expected to be over 1 billion. And, by 2020, the urban population is likely to exceed half of the total regional population. Both intensified future migration and urbanization are likely to reinforce the crowding of coastal areas, expanding the current coastal population from 20 to 40% by 2025. Population is likely to build up along the coasts of West and Central Africa from Senegal to Angola, in Southern Africa, including South Africa and Mozambique, and in the coasts of Eritrea, Somalia, and Djibouti.

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[2] This section is drawn from World Bank (1995) and Cleaver, Schreiber (1994).

These demographic projections have immediate implications for food requirements. When the population base was small, farming was largely pastoral and nomadic with land lying fallow for long periods of time. However, with the rise in population since the mid 1960s, new land, most of which was marginally productive, had to be brought under cultivation. Furthermore, soil erosion in pasture and range areas also contributed towards a decline in fertility. Agricultural technologies, such as intensive crop cultivation, were environmentally destructive. Deforestation was also aggravated due to a large dependence on wood for fuel and building purposes and a lack of regulation on commercial logging. Deforestation, in turn, aggravated soil erosion and degradation led to losses and in biodiversity. In 1980, the forest cover in sub-Saharan Africa was 679 million hectares. Now, it is being depleted at the rate of 3.7 million hectares per year. As much as half of sub-Saharan Africa's farmland and 80% of its pastures and rangelands have been affected by erosion. These developments together resulted in declining per capita consumption.

In light of this deficit, food production now needs to grow faster than population. Assuming a consumption growth rate of 3.3% per annum., the demand for food will triple from 1990 to 2025. If all the theoretically available cultivable land could be brought into production, this demand could be met. However, this assumption is unrealistic because most of this additional land is inaccessible, and competition with alternate uses (livestock production) is likely to intensify. It is estimated that food supply could be increased by about 60% by 2025. Half of this increase is expected from intensification and the rest from the expansion of land. The remainder of the total increase would come from the adoption of more productive technologies, only some of which are currently known. It remains questionable as to what extent this increase can be met through improved technologies. The shortfalls that remain would translate into increased environmental pressure.

Meeting the food challenge would also depend upon overall economic growth. If annual per capita income growth can reach 1.5%, this implies an increase from $530 per capita in 1992 to $828, 30 years hence. Even if this growth is realized, poverty would still remain a major bottleneck in the region and could constrain much of the population to short-term exploitation of the environment.

In summary, although sub-Saharan Africa is a region wealthy in natural resources, it is experiencing a prolonged demographic transition marred by widescale poverty and environmental degradation. This may be a result of political stability in the region, which precluded economic growth during the period and forced the growing population to pursue more extreme measures to attain even a subsistence living. Thus, the challenges that this region faces in terms of the population–environment–development nexus are: (i) feeding people through improved and sustainable technologies while maintaining natural capital in terms of production potential and biodiversity; (ii) facilitating a demographic transition towards a more stable population and a more balanced age pyramid; (iii) guiding migration towards a better population distribution in relation to development potential while mitigating environmental cost, and (iv) making urbanization sustainable, building upon the positive aspects of market growth in cities while averting the deterioration of living conditions.

ANNEXURE II

THE CASE OF SOUTH KOREA[3]

While sub-Saharan Africa represents an area that is best characterized by high population growth and low consumption, South Korea represents the exact opposite: low population growth and high levels of consumption. This case study is of great interest mainly because it has essentially completed its demographic transition, and that too without high degrees of poverty and damage to the environment.

The present population of South Korea is about 45 million, a level which is expected to increase very little in coming decades. During the early 1960s, Korea entered the second stage of its demographic transition, and experienced declines in its mortality rate while fertility remained high. This did not last long, however, as the popular use of contraception beginning in the middle part of that decade brought down the total fertility rate from 6.1 children per woman to 4.1 for the period of 1970–1975, and finally to an estimated 1.6 in 1990. As recently as 1950, South Korea's population was 20 million with an annual growth rate of 3.1%, but this growth declined very quickly, reaching the level of one percent between 1985 and 1990. This amazingly rapid transition took only 20 years.

At about the same time as its demographic transition, South Korea experienced rapid economic growth and industrialization. Its new export-centered policy led to a growth in gross domestic product (GDP) of about 10% per year from the early 1960s to the present. Per capita income rose from US $75 in 1962 to US $4040 in 1988, and expansion was associated with a massive shift from an agriculture-based economy to a predominantly industrial one. Over the same two decades, the urban population grew from five percent of the nation to an expected 81% in 2000, and the portion of GDP from agriculture fell from 38 to 11%.

This phenomenal fall in fertility can be attributed to the voluntary use of contraceptives. Contraception utilization rose from 25% of Korean couples in 1969 to 77% in 1988, largely as a result of government concern about population growth and its focus on family planning. In addition to this interest and the general awareness and enthusiasm of couples and their communities, there were several additional factors that facilitated the decreased demand for children. First of all, there was no religious or cultural opposition to family planning. Korea is a culturally homogeneous country and does not have the ethical problems that some Christian countries, for example, might have. Second, Korea already had a rather high literacy rate, which made spreading awareness about family planning relatively easy. Thirdly, Korea was experiencing economic growth and high employment, which increased the opportunity cost for children and gave couples an economic option other than that of increasing their family size.

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[3] This section is drawn from Kim, van den Oever (1992).

The modern, industrial Korea is not free from environmental damage. Its large growth in income and consumption has led to a sixfold increase in energy use, which in turn, was the cause of a 21 million ton annual increase in carbon dioxide emissions. Besides this, it has seen a vast growth in urban air pollution, industrial waste, and the depletion of its fisheries. Korea is now turning its attention to pollution control and resource conservation, but for many years it was categorically unconcerned about its environment. In fact, smokestacks were previously viewed as signs of economic strength and progress.

In conclusion, the demographic transition experienced by South Korea was vastly different from the one in sub-Saharan Africa. The transition was very rapid and relatively painless – without the poverty and local environmental degradation currently suffered in sub-Saharan Africa; this success can be attributed to South Korea's concurrent economic growth. The growth of GDP provided jobs for its residents, infrastructure for education and public health, and incentives for reductions in fertility. At the same time, it enabled South Korea to care for its increasing numbers and to avoid the poverty which would have induced the populous to consume its natural resources. The pollution in South Korea is recent in nature, and is tied to high levels of consumption rather than population growth and poverty. With its financial wherewithal, South Korea should be able to make swift advances in combating it.

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EFFECTS OF POPULATION PRESSURE AND POVERTY ON BIODIVERSITY CONSERVATION IN THE PHILIPPINES

Maria Concepcion J Cruz[1]

INTRODUCTION

It is widely recognized that poverty and population growth contribute to environmental degradation, yet the linkages are insufficiently analyzed and documented (UNFPA 1991; Shaw 1989; Repetto 1987). As some studies (Cruz *et al.* 1992; Bilsborrow, DeLargy 1990; Malingreau, Tucker 1988; Repetto, Holmes 1983) point out, poverty-related factors are also population variables, and, over time, both place unsustainable burdens on the environment. However, few have looked at precisely how they are interconnected within a particular country setting.

The need to understand the relationship between population and environment, both direct and indirect, and both proximate and ultimate, is especially significant for the poorest of the poor. Whether perceived correctly or not, the poor are seen as causing environmental degradation, particularly in the forest areas of many developing countries (Myers 1991; Bilsborrow 1987). Traditional and indigenous systems of resource use, which have been found to be sustainable at low population densities, are differentiated from the cultivation of forest lands in order to meet the short-term livelihood needs of the growing number of poor migrants. Further, it is the bottom 30% of the poor households who have the highest fertility rates and the least access to information on family planning, education, and social services (UNFPA 1991).

This paper focuses on one aspect of poverty and population: *the increasing number of rural migrants in search of alternative incomes and livelihood.* As employment opportunities are generally limited in the urban centers of many developing countries, coupled with overcrowding and deteriorating facilities, the expectation of pulling migrants into cities has given way to a pattern of rural-to-rural movements, mostly to unoccupied and open forest lands.

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This paper also looks at one form of environmental degradation: *the conversion of forest lands into unsustainable use.* The most critical effect is the loss of biological diversity due to a decline in habitat and species endemism.[2] Although most of the deforestation can be attributed to excessive logging, the activity by itself does not always lead to a permanent change in land use. It is the occupation of logged-over lands, and its use for agriculture by increasing numbers of rural migrants that, together with logging, has created a pattern of significant forest and biodiversity loss in many developing countries.

Using time-series and cross-section information on the Philippines, this paper demonstrates how natural resource management policies, land tenure laws, rapid population increases, and economic policies have contributed to poverty-induced environmental stress. The next section describes the pattern of forest biodiversity decline. This is followed by a discussion on the growth of upland population and rural-to-rural migration, indicating the symmetry between destination regions and critical forest habitats. The subsequent section discusses some of the key factors influencing rural movements. Work done by Cruz, Francisco, Amacher (1996), using an econometric model linking economic, environmental, and demographic factors to migration-induced deforestation, is cited to demonstrate the interrelated effects of economywide and sectoral policies on the environment. The last section summarizes the key findings and offers recommendations for research and policy.

DECLINE IN FOREST BIODIVERSITY IN THE PHILIPPINES

The Philippines has, within its 300 000 km^2 national territory, an unusual assemblage of terrestrial and marine species, including some 12 000 plant species of which 3800 are endemic to the country, 170 000 species of fauna, and approximately 500 species of coral (GEF/World Bank 1994). More than one-half of the total area in the country is forest, which contains about 3500 endemic tree and plant species. Most forest lands lie within jurisdictions of approximately 64 government-managed, national protected areas (parks, wildlife sanctuaries, reserves). However, because of the lack of resources, personnel, and financing, forests still remain virtually unprotected from encroaching hunters, traders, and migrants.

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[2] Endemism is the percentage of flora and fauna species unique to a particular area relative to the total number of species found in that area. High species endemism is often associated with dense habitats (Soule 1986).

THE PROTECTED AREAS SYSTEM

The Philippine government has adopted a nationwide program, the National Integrated Protected Area System (NIPAS), to conserve sites rich in biodiversity.[3] The NIPAS divides the country's land and water resources into 15 biogeographic zones, all of which are recognized as areas of high biodiversity and endemism by the World Conservation Union (IUCN). The map showing these zones is taken from the project document of the GEF and the World Bank financed 'Philippines Conservation of Priority Protected Areas Project (April 1994)'.[4]

The high concentration of biologically rich forests and wetlands in the country comes from its geomorphological history. Large land masses, constituting the country's major island groupings, were previously connected to the Asian mainland and Borneo during the Pleistocene era. This explains the existence of five large and distinct faunal characteristics and the highest endemism among countries in the region. In addition, forests are particularly dense and diverse due to varying exposures to shifting trade winds and seasonal typhoons, mountainous terrains of varying heights and elevation, and peculiar patterns of rainfall (GEF/World Bank 1994).

Although not yet completed for the entire country, the initial results of biological assessments indicate the severe and critical decline in forest habitat for more than one-third of the identified endemic species. Previously dense hardwood trees, mostly old-growth dipterocarp forests, used to cover about 100 000 km^2 during the 1950s, but by the early 1980s, forest area declined to just 20 000 km^2 (World Bank 1989). The 1988 satellite-based national land use survey found that less than 10 000 km^2 of old-growth forests remained concentrated mostly in the biogeographic zones in the northern part of the country (SSC 1988). Although there are still 30 000 to 40 000 km^2 of disturbed or second-growth forests left, these are under threat from small-scale illegal loggers, shifting cultivators, and rural migrants. If these threats are left unchecked, it is estimated that forest cover may not last until the end of the century.

DEFORESTATION RATES

Due to the absence of reliable data on deforestation rates, the estimates of forest loss have ranged from 850 to 2100 km^2 per year. At either extreme, this

[3] The NIPAS was developed based upon a study coordinated by the World Wildlife Fund - US (WWF-US), University of the Philippines Science Foundation, and the Foundation for Sustainable Development Inc., with financial support from a Japan-World Bank technical assistance grant. It was completed in 1991.

[4] This project covers 10 NIPAS sites, representing six of the most important biogeographic zones and covering an area of almost 1.25 million hectares of forests and wetlands.

is still one of the highest in the region. The lower estimate is from the Philippines Bureau of Forest Development for the period 1970 to 1985 (DENR 1988). This is based upon cadastral surveys and records submitted by district logging concessions and timber traders where under-reporting is often the practice to avoid payment of concession licenses and fees (Vitug 1993). The latter estimate of 2100 km^2 per year compares the government land use survey (for the 1970 baseline, see Gulmatico 1988) with more recent satellite information (NRAP 1991). Forest cover declined from more than 34% of land area in 1970 to 24% in 1988. As the land use information does not come from the same sources, patterns of change need to be cross-checked with data on cultivated area. For example, during the 1980s, decline in forest area coincided with the growth of extensively cultivated land in high elevation and hilly plantations and grasslands (NEDA 1987; 1990). Extensive agriculture occurred largely in previously logged-over lands.

As shown in Table 1, all types of forests comprise just 24% of total land area, while extensive cultivation accounts for about 40%, and traditional and intensively cultivated agricultural lands cover less than 33% (SSC 1988). About two-thirds of the remaining forests are lowland evergreens lying between 200 to 800 m above sea level and are dominated by dipterocarp tree species and broad leaf second growth forest and cogon (*Imperata cylindrica*) or talahib (*Saccharum spontaneum*) grasslands. The remaining areas are pine and mossy forests at higher elevations, from 800 to 1500 m or more in the northern and midwestern sections of the country. These forests contain the endemic species of mosses, leafy liverworts, filmy ferns, orchids, vines, *Podocarpus*, oak, *Symplocos*, *Tristania*, *Eugenia*, *Dacrydium*, and *Myrica* (GEF/World Bank 1994).

Due to rapid forest habitat destruction, 60% of endemic Philippine flora are now extinct, and some 57 species of mammals, birds, and reptiles are on the list of endangered species (WCMC 1992). Two endemic species of cultural and historical importance in the country are about to become extinct – the tamaraw (*Bubalus minorensis*) and the national cultural symbol, the Philippine eagle (*Pithecophaga jefferyi*). Although some of these threatened flora and fauna are maintained in sanctuaries, these parks have been degraded in many ways by human encroachments and hunting (Table 2).

OCCUPATION OF FORESTS

Most forests are located in officially classified forest lands (or uplands), while most of other land uses, such as intensive cultivation and urban areas, are in the lowlands. The Philippine government distinguishes uplands and lowlands by slope – 18% (about 10 degrees) and above slopes are considered uplands and forest lands under government or state control; the rest are lowlands or alienable and disposable (A & D) lands which can be privately owned. How-

Table 1. *Land use classification in the Philippines (as of 1988)*

Land use/cover	*Area (km²)*	*Percentage of total area*
Forest	72.26	23.92
Pine	0.81	0.27
Mossy	2.46	0.81
Dipterocarp	66.29	21.94
Closed	24.35	8.06
Open	41.94	13.88
Mangrove	1.49	0.49
Others	1.21	0.40
Extensive cultivation	119.58	39.58
Open in forest	0.30	0.09
Grasslands	18.13	6.00
Mixed grass, brush, plantations, etc.	101.14	33.49
Intensive cultivation	97.29	32.58
Plantation	53.36	17 67
Coconut	111.33	3 75
Others	0 91	0 30
Coconut/ cropland	37.48	12.40
Other cropland	3.65	1.20
Croplands	43.92	14.54
Fishponds	2.05	0.67
Fishponds from mangroves	1.95	0.64
Other fishponds	0.10	0.03
Nonvegetated areas	1.01	0.34
Eroded areas	0.007	0.002
Quarries	0.008	0.02
Riverbeds	0.81	0.27
Other barren land	0.10	0.03
Others	4.39	1.45
Built-up areas	1.31	0.43
Marshy areas	1.03	0.34
Lakes	2.05	0.68
Unclassified	5.46	1.80
Total (all land uses)	302.05	99.96

Note Totals may not add up due to rounding off
Sources SSC (1988), Cruz, Francisco, Amacher 1996

ever, such land classification is not strictly enforced. The Philippines Land Management Bureau (LMB) estimates that as much as 28% of forest lands are in slopes less than 18%, and about 35% of classified A & D lands have slopes in excess of 18% (DENR 1985). Furthermore, LMB reports that in 1981 about

Table 2. *Number of threatened, known, and endemic species in the Philippines (as of 1990)*

Species	*Number of threatened species*	*Number of species known*	*Number of endemic species*
Plants	159	—	—
Mammals	12	166	90
Birds	39	395	172
Reptiles	6	193	131
Amphibians	0	63	44
Fish	21	—	—

Source. WCMC (1992: Tables 13.1 and 17.3).

13% of productive forests and 21% of old-growth forests were in A & D lands and 29% of permanent croplands were found in officially classified forest lands.

The lack of enforcement of land classification criteria and the absence of comprehensive land cadastrals and forest surveys have only served to heighten land conflicts over forests. Laws and administrative procedures remain unclear regarding ownership of forest lands which have been, inadvertently or not, classified as A & D lands. Among these privately owned forests are large-scale timber concessions (Vitug 1993).

A large and growing area of forests are occupied, most of them illegally, by rural migrants. Between 1970 to 1980, the population growth rate in timber concession areas was 3.5% per year, which was almost twice the national growth rate for that period (Cruz, Zosa-Feranil 1988). In order to recognize occupancy rights of migrants and to encourage conservation farming in hilly slopes, the Philippine government established, in 1983, the Integrated Social Forestry Program. Under this program, Certificates of Stewardship were awarded to farmers covering an average of 2.5 hectares over 25 years on a yearly renewable basis (DENR 1990). In 1987, the government expanded the program and introduced two other arrangements. One was the Forest Land Management Agreement, which gave 25-year leases to villages to protect forests. The other program, the Community Forest Management Agreement, awarded use rights to an individual or community for tree planting and maintenance. However, as these programs were aimed at tree planting and had minimal impacts on clarifying property rights, encroachments into unprotected forests continued to increase.

About 15% of forests which are largely uninhabited lie in higher elevation areas where biodiversity remains almost intact. Still largely virgin and undeveloped, these are less attractive for logging due to their remoteness and are unpopular among rural migrants, who prefer the more accessible logged-over or semi-cleared sites. These pockets of forests have become the only refuge for what the Philippine government refers to as indigenous cultural communities (ICCs). These ICCs are indigenous peoples with distinct cultural traditions and practices, including religion, language, and political decision-making systems which are different from the dominant population. Under Philippine law, the ICCs have customary rights to forests. Although now recognized by the Constitution, these rights still need to be clarified by law and administrative procedures (Lynch, Talbott 1995).

PROTECTED AREAS

The Philippine government is yet to complete the national survey of biodiversity resources in forest and coastal areas. Under the NIPAS, an initial list of 64 protected areas, or roughly 80% of potentially rich biodiversity sites, have been declared as national parks, sanctuaries, or reserves (NEDA 1990; DENR 1990). Protected area boundaries, especially in parks and reserves declared prior to 1980, are defined through land cadastral surveys, but more recent satellite information have redrawn these boundaries to coincide with major ecological characteristics (e.g., extent of species habitat and density). Once the boundaries are delineated (or gazetted), the protected area falls under government control regardless of the presence of human settlements inside the area.

The threats of encroachments into protected forests have become critical, considering that there is less than 7000 km^2 of remaining tropical moist forests in the country and only 22% of these have closed canopy cover (Table 3).

Table 3. *Estimates of remaining tropical moist forest and percentage of protected areas in the Philippines (as of 1990)*

Tropical moist forests (TMFs)	*Satellite-based land use survey (1988)*	*IUCN estimate (1990)*
Remaining TMFs		
Area (km^2)	6629	660
Percentage of total land area	22	22
Area with closed canopy forest (km^2)	2435	2950
Percentage of TMF declared as protected area	37	45
Existing (km^2)	—	1775
Proposed (km^2)	—	620

Sources. NRAP (1991); WCMC (1992).

In addition, while more than 60% of the closed canopy dense forests have been declared as parks or nature reserves, some 620 km^2 of forests remain open and unprotected.

POPULATION GROWTH AND RURAL-TO-RURAL MIGRATION

Rapid population growth, lack of access to lowland arable land, inequitable land distribution and landlessness, and worsening poverty create pressures for migration. Although urban migrants still comprise the majority of internal migration in the Philippines, the rate of growth of urban migration has decreased due to growing unemployment in industry and urban services and a general decline in the economy. In contrast, migration towards frontier forest sites, which can be opened up for cultivation, has tripled in size since the 1960s. As a result, more than 17.4 million people, one-third of total Philippine population, now live in the uplands, of which close to 12 million are farming in forest lands. If left unchecked at its current growth rate of over three percent per year, the upland population will double its current size by 2020.

POPULATION GROWTH TRENDS

The Philippines has one of the highest annual population growth rates in the region. Although the rate of growth has decreased in recent years, the population projections still reflect substantial increases in population due to a slower decline in fertility (UN 1991). At an estimated two percent per year increase between 1988 and 2000, another 28 million people may be added to the current population of 63 million before the demographic transition to low birth and death rates occurs sometime in 2015 and 2020 (Bulatao *et al.* 1990).

There is a long history of high population growth rates. Between 1950 and 1985, population grew by 2.8% per year, and by 1985 to 1990, it was still close to 2.5% (UN 1990). Considering its land base, the population density increased from about 190 persons per square kilometer during the latter 1980s to more than 210 in 1990 (NSO 1990). It is, thus, among the most densely populated countries in the world. In addition, because one-half of total land area is classified as forest, large numbers of people are already residing in forests. Further movements into the remaining five percent of the land under primary forest are expected as the demand for cultivable land and fuelwood expands with the growing population.

Furthermore, movements into forests will continue to rise as the number of poor people increase. Over one-half of the current population is below the poverty line and with standards of living below subsistence. The 1983 National Demographic Survey indicates that rural women, on average, have almost twice as many children as their counterparts in urban centers. Regions with higher incomes have much lower registered births, with poor regions' having 5.3 children per woman compared to the better-off regions with 4.7 (De Guzman 1987).

Large increases in the working-age population and the high child dependency burden will continue to exert pressure on the country's resources and economy. During the 1990s, the economy must generate about 4.4 million new jobs each year just to employ the young population who will enter the labor force in the next 10 to 20 years (Nguiangain 1986). Between 1990 and 2015, for example, the working age population is projected to increase from 35.3 to 65.6 million (UN 1990; NEDA 1989).

FOREST AND UPLAND POPULATION

The Philippines, like most other countries, conducts the population census by gathering data on the basis of political and administrative boundaries. This poses problems for measuring forest and upland population. However, by using cadastral surveys and low-flying aerial photographs, the closest approximation of the census enumeration unit that corresponds to forest land boundaries can be applied in estimating forest population. There are 709 municipalities classified as upland or forest, representing 47% of all municipalities and more than one-half of the country's land area (Cruz, Zosa-Feranil, Goce 1988).

The figures in Table 4 make use of the adjusted census boundaries and are cross-checked with government statistics on classified forest and timber areas. Forest population has increased rapidly from 5.8 million in 1950 to almost 17.5 million by 1990. The annual growth rate, on an average, was close

Table 4. *Number, annual growth rate, and net increase in migrant population in forest and upland areas in the Philippines (1950–1990)*

Population factors	*1950*	*1960*	*1970*	*1980*	*1990*
Population in forest and upland areas (thousand persons)	5868	8192.00	11169.00	14440.00	17483.00
Annual growth rate (%)	—	3.39	3.15	2.60	3.93
Met migration rate (%)	—	-4.20	3.40	9.40	14.50
Annual growth rate in timber concession areas (%)	—	4.58	4.72	3.49	nd[a]

[a] no data available.

Sources. Data from NSO adjusted and reported in Cruz, Zosa-Feranil, Goce (1988); 1990 population from Cruz, Francisco, Amacher (1996).

to 3.2% per year between 1950 to 1990, and 3.4% in the past decade alone (Cruz *et al.* 1992). If present trends continue, the upland population may increase by approximately one million persons each year in the next decade.

The upland population has grown more rapidly than the national population because of increasing in-migration from rural areas as well as higher fertility rates. About 38% of all interregional migrants moved from overcrowded or low productivity agricultural regions to the less densely populated and more fertile irrigated areas throughout the 1960s (Fleiger 1976). It was during the 1970s that urbanward movements intensified while frontierward migration decreased. However, by the 1980s, migrants accounted for 14.5% of total upland population.

Upland population densities were relatively low during the early periods of in-migration throughout the 1960s. However, with rapid population increases, many upland sites in the 1970s already registered densities of over 300 persons per square kilometer. The average density in lands with less steep slopes is higher – 260 persons per square kilometer – compared to the moderate and steep lands.

Forests in steeply sloping lands have experienced high rates of deforestation and soil loss. For example, in the upstream sections of one of the country's largest reservoirs, the Magat watershed, erosion losses averaged less than two tons per hectare for lands under forest cover but increased to between 122 and 210 tons per hectare in the upstream lands occupied by migrants engaging in unsustainable grazing and upland farming (David 1988).[5]

UPLAND MIGRATION PATTERNS

Together with urbanization, interregional rural-to-rural migration is a dominant factor in the distribution of population in the Philippines (De Guzman 1987). Although in-migration to cities continues to increase, resulting in uneven concentration in urban centers, large and growing numbers of migrants are also moving into agricultural and forest lands. Some of these movements are motivated by government programs, such as the planned settlement schemes during the 1960s (Paderanga 1988).

With the exception of the years between 1970 and 1975, the number of net upland migrants continued to increase throughout the four census peri-

[5] The on-site replacement cost of soil nutrients lost with this level of erosion is estimated at about US $50 annually per hectare (Cruz, Cruz 1991). In the Magat watershed alone, the gross annual economic loss is US $9.0 million for an area that covers 176 800 hectares of open, cultivated and grazed lands. World Bank (1989) estimates the national annual erosion loss to be in the order of US $100 million.

ods. Between 1980 and 1990, upland migrants grew to almost three times the number that migrated between 1960 and 1970. Between 1980 and 1990, there were more than 3.5 million net upland migrants, accounting for 40% of all interregional migration during that period. It was also during this period that the number of upland-to-upland movements increased dramatically, from less than six percent during the 1960s and 1970s to more than 38% of migration during the 1980s

This pattern of lowland-to-upland and upland-to-upland movements is correlated with the rise in logged-over areas and mines. As Fleiger (1985: 138) explains

> *...logging camps and mines are usually surrounded by open, cultivable lands and offer to the families living there the possibility of augmenting farm incomes...logging and mining do not require the skills which industrial jobs available in and around Manila demand.*

CONSEQUENCES OF INCREASING MIGRANT ENCROACHMENTS

Expanded Cultivation in Forests

By the mid-1970s, the agricultural frontier in the lowlands was already closed, or near the physical and economic limits for intensified lowland cultivation. Together with unequal land distribution, landlessness, and deepening poverty in the rural areas, the movements toward open, uncultivated uplands increased. The expansion of farming in forests, especially in moderate to steeply sloping lands, required adoption of conservation practices to reduce soil losses. However, most migrant farmers were unfamiliar with such techniques.

Cultivated upland forest lands accounted for less than 10% of total cultivated area in 1960, compared to over 30% in 1987. As shown in Figure 1, cultivated area in forest increased from 5820 km^2 in 1960 to more than 30 900 km^2 in 1987. Between 1980 and 1987, total cultivated area in forests grew by 2700 km^2, or a rate of growth of 7.6% per year. Close to 60% of the increase in upland farming (some 1600 km^2) occurred in logged-over lands with slopes between 18 and 30%, degraded grasslands, and shrublands which were unsuitable for cultivation (World Bank 1989).

The pressures to increase food production are high. The country needs to expand cultivation by 3000 to 5000 km^2 a year in order to accommodate food requirements of increases in national population during the 1990s (FAO 1984). This means that with the closed lowland frontier, agricultural expansion will occur in lands that are in, or near, forest reserves with thin and highly erodible soils.

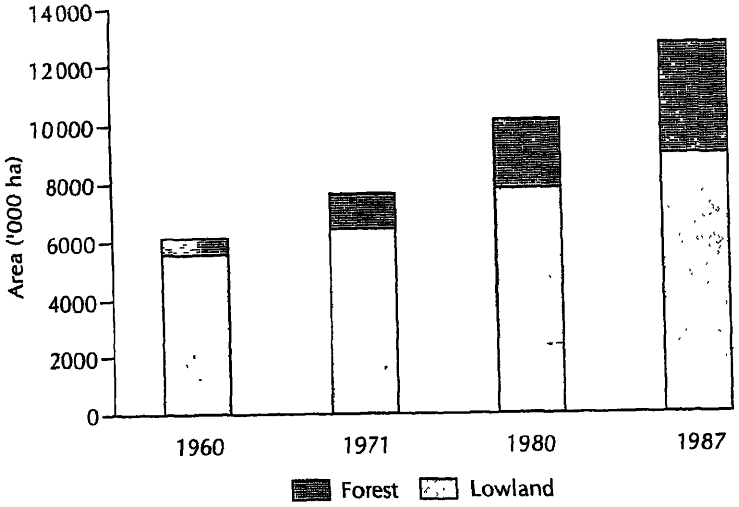

Figure 1. *Expansion of agriculture in the forest lands of the Philippines (1960–1987)*
Source. NEDA (1989).

Increased Fuelwood Consumption

A large section of the population continues to rely on fuelwood for cooking, charcoal making, tobacco curing, and other household industries. The total consumption of fuelwood in 1985 was estimated at 28.5 million cubic meters (DENR 1988); roughly equivalent to the volume of wood lost from deforestation (Cruz, Repetto 1992). In contrast, reported commercial timber harvests during the same year accounted for only 3.6 million cubic meters.

More than 80% of cut fuelwood is for household use. Upland households rely entirely on fuelwood for cooking; and in the rural areas, 90% of households, and about one-half of urban households, rely on charcoal and wood for cooking (Tesoro 1989). Around one-fifth of fuelwood supply comes from family woodlots or backyards; the rest from nearby forests.

Fuelwood usage and demand is likely to increase in the future, not only because the population is growing but also because of the high price of kerosene and natural gas. The 2.5% per year growth in fuelwood consumption during the 1970s increased to more than 4.1% per year between 1980 and 1985 (FDC 1987). By 2000, more than 55 million cubic meters of fuelwood is expected to be consumed yearly; of which 80% is expected to be supplied from forests (Tesoro 1989). Yet, the total remaining volume of timber in 1987 was estimated at only 903.8 million cubic meters (Cruz, Repetto 1992).

Biodiversity Loss

As shown in Table 5, close to 1.2 million people reside within the boundaries of 50 out of the 64 protected areas identified by NIPAS. According to the population census, the number of people inside these areas increased at an

Table 5. *Indicative list of protected areas identified in the national integrated protected area system of the Philippines: number of municipalities, population, and annual growth rate*

Biogeographic zone	*Identified protected area*	*Number of municipalities*	*Population (1990)*	*Annual growth rate (1980–1990)*
Batanes	Sabtang/Itbayat Islands	1	628	1.2
	Mt Iraya	1	609	1.2
	Yami *et al.*	2	916	1.4
Central Cordillera	Magat forest reservation	4	23902	2.8
	Mt Pulog	3	13514	2.5
	Mt Data	3	16943	2.5
Sierra Madre	Sierra Madre Mts	3	23881	2.3
	Palani Island	2	8473	2.1
	Cagayan River	nd[a]	nd	nd
	Mt Binuang	2	4149	2.5
	Mt Arayat	2	73189	3.5
Southern Luzon	Balayan Bay	nd	nd	nd
	Pagbilao Bay	nd	nd	nd
	West Calatagan Reefs	2	66146	3.1
	Taal Lake	3	46944	3.4
	Lobo	2	13438	2.8
	La Laguna Marsh, Lopez	2	15495	2.6
	Quezon National park	3	13320	2.8
	Mt Makiling	3	27539	3.1
	Mt Banahaw	3	17965	3.0
	Minasawa Island	nd	nd	nd
	Tauabas Bay	nd	nd	nd
	Manlubas Swamp	2	21577	2.5
	Ragay Gulf	nd	nd	nd
	Mt Lobo	2	27515	2.1
	Bicol National park	3	72560	3.5
	Mt Isarog	3	53016	3.1
	Mayon Volcano	3	16011	2.1

(Continued...)

Table 5. *(Continued...)*

Biogeographic zone	*Identified protected area*	*Number of municipalities*	*Population (1990)*	*Annual growth rate (1980–1990)*
	Mt Bulusan	3	5621	2.5
	Bulusan Lake	nd	nd	nd
	Mt Pulog-Palay Mataas	3	13105	2.1
	Na Gulod	2	1018	1.8
	Lake Buhi	3	57495	4.1
	Lake Bato	2	35294	3.1
	Aurora National park	3	49501	3.0
Zambales	Mt Pinatubo	3	15337	1.5
	Candaba Swamp	3	68215	3.1
	Bataan National Park	3	19719	1.8
Mindoro	Mt Iglit Baco	3	7549	2.5
	Mt Halcon	2	13609	2.1
	Lake Naujan	nd	nd	nd
	Puerto Galera Bay	nd	nd	nd
	Apo Feef	2	2332	1.2
Western Visayas	Mt Canloan	4	52452	2.6
	Philippine Deer Sanctuary	2	6243	1.2
	Taklong Island	nd	nd	nd
Eastern Visayas	Mahagnao	2	6638	2.1
	Timber Production Marketing Corporation	nd	nd	nd
	Wilder	nd	nd	nd
	Lake Danao	3	19900	2.5
	Rajah Sikatuna			
Calamian	Coron	2	9958	2.1
Palawan	El Nido	2	18832	2.5
	St Paul	2	31538	2.5
Sulu	Turtle Islands	2	1196	1.3
Mindanao	Mt Malindang	2	9987	2.1
	Rungkunan	2	6670	1.8
	Lake Dapao	nd	nd	nd
	Salikata	3	18343	2.1
	Mt Apo	2	7336	1.6
	Siargao	2	25202	2.5
	Mt Kitanglad	3	13676	1.4
	Agusan Marsh	2	13530	2.0
Liguasan	Liguasan Marsh	nd	nd	nd

[a] no data available.

Sources. GEF/World Bank (1994: Annex B, pp. 1–2); population data from NSO (1980; 1990) reported in Cruz, Francisco, Amacher (1996).

average of 2.4% per year between 1980 and 1990. Some sites have grown tremendously due to tourism, proximity to market centers and towns, small-scale logging, and fuelwood cutting, with average annual growth rates in excess of 3% per year (e.g., Mt Arayat, Bicol National Park, Mt Makiling).

There are small patches of primary forests which contain some original vegetation and, thus, harbor the country's most important biodiversity species. For example, the 10 priority protected areas included in the GEF/World Bank project have the country's largest collections of native and endemic flora and fauna, and still maintain relatively low density populations (see Table 6). There are more than 142 000 people occupying about 5000 km^2 of land area. The population growth rate is modest at 1.8% per year between 1980 and 1990. Four of these areas constitute ancestral lands of indigenous peoples and their populations have remained fairly stable over the years.

However, while human settlements have not grown appreciably inside these protected areas, in the buffer zone, which includes municipalities adjacent to the boundaries, population has been increasing at an average of 2.5% per year. Although not everyone in the buffer municipalities exploits resources inside the protected area, the numbers show the potential pressures that can arise from population densities that are substantially larger and growing (see Table 6). Moreover, since more than 75% of the people in these areas are migrants (or born elsewhere), it is expected that the bulk of future pressures will come from new migrants opening up lands for cultivation.

There will also be pressures from the existing buffer area population. For example, results of a socioeconomic survey in the vicinity of Mt Canlaon National Park (three municipalities; 230 households) indicate that the major occupation is cultivation of upland rice and coconut, followed by charcoal making and selling of firewood (IAST 1990). More than 83% of households surveyed derive about one-half of their income from fuelwood cutting in nearby forests, some of which are inside park boundaries.

FACTORS INFLUENCING PATTERNS OF FOREST MIGRATION

The descriptions of changes in population, poverty, and forest land use over a long time period (from 1950 to 1990), and over a cross-section of the country, establish the direction these processes are likely to take in the future. For example, because population growth and poverty create strong incentives for moving into forests, there will be pressures for expanding cultivation into forest lands, increasing consumption of fuelwood, and occupying forest lands without clearly defined property rights.

However, such a descriptive analysis is often insufficient for policymaking, especially if the interactive effects among these processes remain largely unknown. More rigorous analysis is needed in the design of relevant

Table 6. *Land area, population, and annual growth rate in 10 priority areas and number of municipalities, population, and annual growth rate in the buffer zone (1980–1990)*

Priority protected area	*Land area (km²)*	*Population (1990)*	*Annual growth rate of population (1980–1990)*	*Number of municipalities in the buffer zone*	*Population in the buffer zone (1990)*	*Annual growth rate of population in the buffer zone (1980–1990)*
Mt Canloan National Park	323.5	52452	2.6	4	124716	2.6
Northern Sierra Madre Nature Park	2402.3	23881	2.3	5	85689	2.8
Batanes Landscape and Seascape	203.2	1122	2.1	3	17241	2.5
Siargao Wildlife Sanctuary	603.9	6338	2.6	4	57200	2.8
Bataan Nature Park	271.7	19719	1.8	3	33904	2.5
Mt Kitanglad Nature Park	311.4	13676	1.4	4	45923	2.5
Apo Reef Nature Park	0.29	2332	1.2	3	46468	2.5
Mt Apo Nature Park	654.8	7336	1.6	3	38092	2.5
Agusan Marsh and Wildlife Sanctuary	224.6	13530	2.0	4	63169	2.5
Turtle Islands Marine Nature Park	3.92	1926	1.3	2	29652	2.5

Sources. GEF/World Bank (1994. Annex C, pp. 1–9); population data from NSO (1980) reported in Cruz, Francisco, Amacher (1996).

macroeconomic and sectoral policies. Such analysis will be useful in predicting the impacts, for example, of a population reduction policy in the rural areas in terms of lower deforestation rates.

ANALYTICAL MODEL OF FOREST MIGRATION

The discussion of a model to determine the factors which motivate people to move out of rural origins and to settle in forests is based upon econometric work done by Cruz, Francisco, Amacher (1996). This econometric model, using a multinomial discrete choice framework, accommodates the many choices facing a potential migrant. It recognizes that an individual migrant faces various potential destinations. The decision to move is affected by a complex set of potential gains.[6]

The model makes use of data from three sources: (i) migration information based on place of birth and place of residence in 1985 contained in the 1990 Philippine census; (ii) socioeconomic data from various government series; and (iii) a socioeconomic survey of lowland and upland communities (IAST 1990).[7] Based on these varied sources, it was possible to analyze migration streams from 31 origins to 52 destination places, or a total of 3898 observations.

KEY FINDINGS

Most of the empirical evidence linking population growth and deforestation support the view that large population densities contribute significantly to deforestation, either directly or through interactions with other socioeconomic and environmental factors (Cruz *et al.* 1992; Panayotou 1991; Repetto 1990). At the same time, there are many, and complex, underlying causes of high population densities in forests, including the 'push' factors of population growth and poverty, and the 'pull' forces that make forests attractive destination places. For example, areas with high upland population densities and increasing in-migration are the semi-cleared forests, logged-over sites, and timber concession areas. These forest lands attract migrants due to their relative accessibility.

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[6] Such discrete choices are especially suited for the Philippines. There are over 70 provinces and 709 upland municipalities. Further, forest lands vary in terms of their suitability for cultivation.

[7] The sampling frame of this national survey was explicitly designed to capture differences in lowland *versus* upland areas. The major limitation, however, is that not all provinces were included in the sample, but this was offset by adjusting income data with information from other sources (e.g., published agricultural income surveys and records of government departments).

The results of the model are presented in Table 7.[8] As there is no single set of factors that can fully explain forest migration, the model looks explicitly at the combined effects of economic, environmental, and demographic factors. Clearly, the implications of such a result have to do with the types of in-

Table 7. *Multinomial discrete choice estimates of determinants of forest migration*

Migration factor/expected link to forest migration	*Coefficient*	*Standard error*
Economic factors		
Average household income	3.97**	1.465
Poverty incidence (%)	−3.74	1.216
Average upland/forest land income	0.208**	0.058
Average provincial lowland income	−0.038	0.067
Unemployment rate in province (%)	18.87	20.680
Population employed in agriculture (%)	−1.97	2.137
Farm area tenancy/lease rate	0.11	0.260
Index of cost of long-range/long-distance migration	−33.03**	1.010
Urbanization rate in province (%)	−0.32	0.427
Literacy rate (%)	−11.53	20.490
Environmental factors		
Upland/forest cultivated area (km^2)	−1.54*	0.922
Arable land in province (km^2)	0.519	0.614
Land under extensive cultivation (%)	0.494	0.416
Land under intensive cultivation (%)	1.081**	0.438
Forest land in province (%)	0.906	0.770
Land area with greater than 30% slope in province (%)	0.352	0.255
Public-forest land in province (%)	1.05**	0.322
Road density in upland/forest area (km^2)	1.27**	0.468
Demographic factors		
Lowland population in province (1980)	3.55**	1.929
Upland/forest population (1980)	0.78**	0.302
Upland/forest population density (1990)	−1.63	1.200
Annual population growth rate (1980–1990)	1 37**	0.340

Notes

1 Log likelihood is −292 39, F-Statistic is 0 0033
2 The symbol (*) denotes significance at 1 10 level and (**) denotes significance at 0 05 level.
3 All factors/variables refer to destination province, unless noted otherwise
4 Index of long-range/long-distance migration equals one if upland migration is to another province, zero if within province

Source Cruz, Francisco, Amacher (1996 Table 7, p 19) terventions that are needed in controlling migrant encroachments into forests. For example, intersectoral programs addressing the 'push' factors associated with poverty alleviation and population reduction need to be coordinated with policies related to land tenure, rural credit, and employment generation. At the same time, the model shows that these programs should be linked to policies that 'pull' migrants into forests, such as land classification schemes and property rights in forests, roads, other infrastructure, logging and timber concessions, and fuelwood and energy pricing policies.

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[8] As this is not a standard migration model, there are no separate classifications of 'push' and 'pull' factors. For information on demographic migration modelling using environmental variables, see Bilderback (1986).

The following key findings describe the set of factors which are significant within such an intersectoral framework.

Economic Conditions: Income and Poverty

Since the incomes of migrants are much lower than the national average, the costs of moving over long distances serve as a deterrent to forest migration, accounting for a significant reduction in movements towards more remote, inaccessible forests. Aside from costs, the important and policy-relevant findings relate to income and poverty. As expected, an increase in average household income and a reduction in the incidence of poverty at the places of destination significantly increase migration into forests. By contrast, the results suggest that targeted reforms, which increase lowland incomes, can improve economic well-being at the places of origin, thus reducing the incentives to move.

Non-availability of Cultivable Lands

Provinces with large areas under intensive cultivation, and working through the effects of unequal land distribution, landlessness, and rising unemployment in agriculture, increase forest migration. Although not measured directly in the model, these results are closely related to the availability of agricultural land and employment opportunities, which tend to slow down migration. Effective rural development programs, which address issues related to land access, tenure, and employment at the places of origin serve as incentives to stay, thereby reducing pressures for opening up forest lands for cultivation.

Property Rights in Forests

Since the data on property and tenure in forests is not available, the model makes use of a proxy – the percentage of public forest land in the place of destination. Since more than one-half of the country's land area is classified forest under government control, efforts to protect these lands have been ineffective. The result is rampant occupation of forests by migrants who perceive these lands as virtually 'open access' areas. Thus, the larger the percentage area under public forest classification, the more the migrants it receives. The implication is that the government needs to enforce a rational land classification scheme and provide clearly defined property rights to forest occupants, who can be more effective in enforcing use rights and preventing future migrant encroachments.

Accessibility of Forest Sites

An interesting result is that the purely physical attributes of forest lands (e.g., slope, soil type, elevation, terrain), or those which provide indications of the area's suitability for occupancy and agriculture, did not appear as important determinants of migration. In addition, a migrant's choice of destination is not affected by how much arable land is left in the province. Instead, what appears more important are policies affecting the perceived attractiveness of forest sites (e.g., road access, tenure), rather than purely on-site physical factors. This is supported by long-term and cross-section migration data showing migrant concentrations in logged-over sites and forest lands near roads and markets. Thus, policies on rural infrastructure at or near the frontier; property and tenure in forests; and forest land classification and allocation systems can play important roles in controlling the volume and direction of migration.

Population Density

Demographic factors are also important. Large lowland population densities at origin positively influence migration. In contrast, upland density, by itself, did not have a significant impact on migration, but upland population growth rate, which reflects demographic expansion, increases migration. This is understandable since density reflects a 'crowding effect' on the resource and is most useful in places with uniform land capability or potential. For example, a low population density of 50 to 100 persons per square kilometer in forests may, in fact, already imply crowding since only a limited area can be easily cleared and cultivated, given the topography and terrain.

The results show that migrants are attracted to forest areas that have large populations, as shown from evidence of concentration of movement into already dense forests in the 1980 to 1990 migration survey. This observation is consistent with village surveys in forest areas in India where small forest communities with 10 to 25 families experienced difficulties in mobilizing resources for tree planting and farming compared to their counterparts in larger forest communities with 50 to 75 families (Agrawal 1996).

The rates of upland cropland expansion are also more rapid in provinces with already large forest populations. The only exceptions are the remote, high elevation forest areas which are the sites of the biodiversity conservation protected parks and sanctuaries. However, these areas, although containing low population densities, have begun to experience substantial increases in fuelwood cutting from nearby villages.

CONCLUSIONS

Addressing the root causes of forest and biodiversity loss will require interventions that are cognizant of the interrelated effects of population, poverty, and environmental degradation. Economic and social policies that help the poor will have significant environmentally beneficial impacts if these are combined with programs that reduce the attractiveness of opening up new lands for cultivation. Property laws and clearly defined land classifications at the frontier are just as important as health and family planning programs in addressing the problems of deforestation and biodiversity loss.

This paper does not discuss the range of issues and recommendations for an intersectoral approach to forest and biodiversity management. However, the following are suggested as starting points for designing such an approach.

EXAMINE LONG-TERM TRENDS IN POPULATION DISTRIBUTION AND POVERTY

The Philippines case study demonstrates the importance of establishing a long-term and cross-sectional database that provides the linkage between changes in population distribution and incidence of poverty with deforestation patterns. Population growth and migration can be evaluated in terms of economic and social policies within a particular time period and area. The insights gained from the historical descriptions will be valuable in setting up the parameters for more detailed quantitative analysis.

DETERMINE THE KEY POLICY VARIABLES

As resources are limited, relevant interventions will have to be targeted to specific policy reforms which have the greatest impacts on reducing biodiversity loss. Similarly, better designed programs and activities, which address the immediate problems or threats to forest and biodiversity resources, can be linked to key policy variables. The econometric model shows, for example, that roads and ill-defined property rights in forests contribute to larger in-migration at almost the same scale as that at which logging opens up new areas for would-be migrants.

FOCUS ON COMMUNITY-BASED PROGRAMS

The evidence suggests that, at least for the Philippines, community-based programs will be important for the long-term sustainability of resource use. Population sizes are large, and growing rapidly, in many upland sites. Some of the newly opened forest farms are already in steeply sloping lands where soils are fragile, indicating a decline in availability of the more accessible uplands. At the same time, new forms of property management among upland residents, including various forms of common property regimes, have emerged in response to the need to enforce controls over future migrant encroachments. Unless the existing use-rights to the uplands are recognized, especially those belonging to indigenous peoples in the remote forests, there will continue to be tension in access to resources which will have the effect of discouraging adoption of longer term conservation practices.

DIFFERENTIATE DEFORESTATION FROM DEGRADATION

Both forestry statistics and land classifications in the Philippines do not differentiate between changes in forest cover due to logging and other forms of biomass reduction, such as fuelwood cutting and collection of nontimber forest products. Although it has been shown that logging eventually leads to the permanent conversion of forests into agriculture, the effects of forest degradation remain largely undocumented and under-reported. This will have significant implications on the manner in which forest and biodiversity resources are monitored in the country and the effects that a weak database will have in the design of programs for maintaining the habitat of endangered and endemic species. As degradation, in terms of biomass reduction and habitat fragmentation, is closely linked with the activities of large numbers of people, solutions will have to come from policies which deal with the delivery of family planning, health, and social services as well as with poverty alleviation programs.

ESTABLISH THE LINKS TO ECONOMYWIDE POLICIES

The results of the migration analysis indicate the close interaction between economywide policies and environmental degradation. The linkages are many and complex but surely not intractable. For example, the price of kerosene and the high costs of electric-, gas-, and kerosene-based cooking appliances have encouraged widespread use of charcoal and fuelwood. Agricultural policies that affect rural incomes and employment play important roles in establishing the correct incentives for people to stay while the domestic price of timber and cut wood motivates increased small-scale logging to meet local demand for housing and furniture. These observations support the need to look at both forest sector and economywide policies in designing programs for sustainable forest management, as well as the need for innovative interministerial cooperation.

TRANSLATE RESEARCH RESULTS INTO POLICY-RELEVANT OPTIONS

The usefulness of research such as this lies in its translation into policies and activities. Specifically for the Philippines, the key policy implications are that alleviating poverty and reducing pressures from population growth will have tremendous effects on forests and biodiversity resources. As a general, long-term approach, the country is moving in the right direction when it launched its rural development and decentralization programs aimed at increasing rural incomes and employment. However, incentives for motivating industry and infrastructure development in the rural areas still need to be strengthened and followed through with rational land classification policies.

Secondly, the research results support the government's land redistribution policies. Through land tenure reforms and expanded agricultural credit schemes, the root causes of out-migration can be addressed. To be more effective, the scope and the budgets for carrying out these programs will have to be expanded to cover twice as many provinces and beneficiaries. There are also numerous advantages in coordinating implementation of these programs with nongovernmental organizations, the private sector, and other groups of the civil society.

Together with rural development, the country needs to allocate more resources to outreach schemes that improve the delivery of family planning, health, and social services. As fertility rates cannot be expected to fall unless these services are available to rural women, population programs need to be accorded the same kind of priority as agricultural and economic plans.

Lastly, on-site and forest sector policies are important. These policies should be aimed at reducing the attractiveness of forests by extending enforceable property rights to current forest occupants and indigenous peoples. The confidence and support of these people are vital so that they become partners in ensuring sustainable forest use and in controlling future encroachments.

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PERCEPTIONS ON COMMUNITY PARTICIPATION IN POPULATION AND ENVIRONMENT IN TRANSMIGRATION AREAS: A CASE STUDY OF LAMPUNG, INDONESIA

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INTRODUCTION

Indonesia ranks as the fourth most populated country in the world, preceded by China, India, and the US. The total population in 1990 was 179.3 million, and was projected to be 195 million in 1995. A major problem facing Indonesia is a high rate of growth of population (around 1.6%) and its uneven distribution – about 60% of the population of Indonesia lives in Java, which occupies only six percent of the total land in Indonesia. To overcome this problem, the Indonesian government introduced a transmigration program – the largest available program in the world to move people from Java and Bali to other islands. In the past, this program was introduced by the Dutch and was called colonization.

The province of Lampung, in Indonesia, is located in the southern part of Sumatra. Lampung population has increased tremendously, from 6 million in 1990 to 6.5 million in 1995 with an annual growth rate of 1.69%. Migrants contributed about 0.35% of the Lampung population growth rate.

This high growth reflects the success of the transmigration program because, over the last two decades, most migrants in Lampung were self-supported. One of the main reasons for this can be attributed to the proximity of the Lampung province to West Java (an hour and a half by ferry). Migration, however, can also have adverse impacts on the environment.

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THE IMPACT OF TRANSMIGRATION ON ENVIRONMENT IN THE PROVINCE OF LAMPUNG

The first province to have experienced transmigration in Indonesia was Lampung. This transmigration program (colonization) was started in 1905 by the Dutch colonial government, which reallocated people from Java to Gedong Tataan. Since the initiation of this program, Lampung has been accommodating migrants from Java. This transmigration process has taken place from time to time and can be categorized into four phases, as outlined below (ROMT 1988).

COLONIAL ERA TRANSMIGRATION

From 1905–1942, during the Dutch colonization, 44 681 households (hh), or a total of 180 020 people were reallocated into Lampung from Java. During the Japanese occupation, 6329 hh or 31 700 people were moved.

PRE-PELITA TRANSMIGRATION

During the period 1950–1969, 53 280 hh or 220 663 people were reallocated to South Lampung, Central Lampung, and North Lampung.

GENERAL TRANSMIGRATION BEFORE ACT 3/1972

Before Act no. 3/1972, the province of Lampung witnessed 21 types of transmigration programs sponsored by various government institutions, such as the Ditjen of Transmigration, the Ditjen of Social Work, Hankam Kwarnas (National Defence), Pramuka (Scouts), Integrasi ABRI (the military integration), Pamen, Banpres (the Presidential grant), and Polri (the Indonesian police force). During this period, 15 241 hh or 71 945 people were reallocated into Lampung.

TRANSMIGRATION AFTER 1972

After 1972, the Ministry of Transmigration has been responsible for all transmigration activities in Indonesia. The number of migrants reallocated into Lampung has continued to rise since. During Pelita I (the First Five Year Development Program), 15 539 hh or 69 658 people were reallocated into Lampung. In the Second Five Year Development Program (Pelita II), 6500 hh, or 28 999 people, were reallocated.

Meanwhile, the success of the government's transmigration program induced spontaneous migration into Lampung. These spontaneous immigrants came to Lampung through immigrants from Java who were already residing there, or from other parts of Sumatra. The flow of these immigrants was generated by the strategic location of the Lampung province, which is ideally located along the transportation route between Sumatra and Java.

The flow of immigrants to Lampung, both spontaneous and through government programs, increased the size and the rate of growth of population. Population growth rate in Lampung was 5.77% between 1971–1980. This rate includes the birth rate (2.33%) and the flow of migrants (3.44%). Population density in Lampung also increased. In 1971, the population density was 78 persons per square kilometer; by 1990, it had reached 170 persons per square kilometer.

Unfortunately, this high population growth rate was not followed by equal population distribution among the *Kabupaten*, (regencies) in the Lampung province. This could be seen by the various density rates in each Second Level Administrative Region (*Daerah Tingkat* II or *Dati* II). The regency of West Lampung has an area of 4950 km^2 and a population size of 309 050, whereas the municipality of Bandar Lampung, with an area of 169 km^2, has a population of 636 418. Differences in the area and the size of population have resulted in varying density rates in every *Dati* II.

This increasing population growth rate has exerted increasing pressures on the land. Areas that were formerly forest lands were converted into farmlands and settlements where new houses, hospitals, roads, and other structures have been built.

The data collected by the *Kanwil Kehutanan* of Lampung (the Regional Forestry Office) showed that at least 416 021 hectares have been converted from forest lands to farmlands and settlement areas. Only 26.03% or 817 093 hectares of land in Lampung now remains under forest cover.

This is lower than the minimum requirement set by the 1967 Forestry Law, which stated that 30% of the total area should remain under forest. By 1990, however, forest cover in Lampung had declined to 22.09%.

As shown by the *Kanwil* data, the depletion of forest land increased pressures on the environment. The need for housing and farmlands led to excessive deforestation. This situation is prevalent all over Lampung and has been continuing for a long time. Noticing the imbalance between the availability of land and population size, the regional government of Lampung has banned the entry of immigrants. Since the beginning of the Fourth Five Year Development Program (Pelita IV), Lampung is no longer a designated area for immigrants; instead, it is a 'sender'. During Pelita IV, there was an outflow of 787 hh or 3432 people from Lampung to Riau to work at the *Perkebunan Inti Rakyat* (PIR) under Pelita V (the Fifth Five Year Development Program). Lampung exported 400 hh or 1471 people to Bengkulu, Jambi, and Riau.

Besides conducting outmigration programs, Lampung has also initiated local transmigration by reallocating people from protected forest lands, flood-prone areas, and river banks (*daerah aliran sungai* or *das*). This process of uprooting covers the areas of Gunung Balak and Way Jepara in Central Lampung, Kota Agung Utara and Batu Serampok in South Lampung, and Bukit Ringis and Way Kenali in North Lampung, consisting of over 35 000 hh. From this number, only 13 751 hh have been reallocated.

A number of factors are responsible for preventing the operation of transmigration. As compared to the original location, the new location has fewer facilities (especially in the case of migrants from Gunung Balak). It shows differences in the quality of soil and in the acid degree content of this soil, causing crop failure. As a result, many farmers have moved back to their original location, neglecting the new location. The government, on the other hand, insists on conserving protected forest lands and flood-prone areas. There have been rumors that the citizens of Gunung Balak do not wish to move out and that outmigrants from Gunung Balak are also moving back into that area. These natives account for the highly fertile soil of Gunung Balak as compared to the not-so-fertile land of North Lampung, as their reason for wanting to move back to their original land. The farming methods of Gunung Balak are inappropriate for the infertile land of North Lampung. Given these problems, it would be interesting to study the society's perceptions towards the environment and their contributions towards its conservation.

CONFLICTS OF LAND USE: A CASE STUDY OF GUNUNG BALAK

The section above discussed the emergence of land use problems in Gunung Balak, the Central Lampung Regency (*Kabupaten Lampung Tengah*). Gunung Balak, being a fertile land, attracted a large migrant population from neighboring villages. The Chief Administrator of Lampung declared this area as forest land under Register No. 38 on 30 November 1935. In the 1960s, with the approval of the forest authorities, this area was cleared of its forests by the military and the migrants. Initially, this process of deforestation was confined to selective tree cutting, which then gave way to the interplanting system on account of high fertility level of the soil in the region.

In the meantime, a larger number of people migrated into this region. Before long, many hamlets were built, which later grew into villages, requiring public services. Faced with the reality of this development, the Regent of Central Lampung (*Bupati Lampung Tengah*) confirmed the existence of the hamlets and granted them the status of a preparatory village, through Reference No. 8/1.K/P/Pom/74 dated 20 April 1974. Eventually, the region of Gunung Balak was designated as an independent *kecamatan*, (district or third level administrative region). Through the Governor's Decision No. 6/85 D.I/HK/1974 dated 13 June 1974, Gunung Balak was confirmed as a candidate district (*kecamatan*) consisting of 13 preparatory villages with an Administrative District Office at the Sidodadi village. The 13 preparatory villages include: Way Abar, Purwokencono, Bandung Jaya, Ogan Jaya, Sidodadi, Sri Widodo, Sri

Kaloko, Sri Katon, Sri Mulyo, Bandar Agung, Sidorejo, Brawijaya, and Majapahit.

The development of the area was, however, terminated because the government planned to build an irrigation system at Way Jepara Lake, located in the north of the villages in Gunung Balak district. People living in the villages, located in the catchment area of 13 000 hectares, had to abandon their homes for this project. The distance between the villages and the Way Jepara Lake varies from 2–21 km. 13 years after the Governor's decision to confirm Gunung Balak as a candidate district, the Administrative District Office and all other representative offices of Gunung Balak were abolished. To realize this action, the governor stipulated a Decree No. 6/237/B-I/HK/1987 dated 10 October 1987. Nine villages were vacated for reforestation, and four others were administratively transferred to neighboring districts (*kecamatan*).

The villages of Sidorejo and Brawijaya were incorporated into the Jabung District, and the Bandar Lampung and Majapahit villages into the Labuhan Maringgai District. However, in 1993, when the Majapahit village had to be abandoned, the villagers were reallocated to North Lampung through the local transmigration program.

The status of the three remaining villages – Sidorejo, Bandar Agung, and Brawijaya – of (former) Gunung Balak is weak. In addition, there were problems regarding the policies of the local government and the expectations of the villagers.

The case of Gunung Balak shows that the problems regarding the environment require more than just understanding and participation. It also needs to incorporate a firm and consistent government policy. In a period of less than 30 years (from the beginning of the 1960s to the end of 1980s), government policies changed frequently have often been contradictory. In the 1960s, the Regional Forest Office allowed people to cut down trees using the selective tree-cutting method, and plant crops using the interplanting system. By 1974, the Gunung Balak region was promoted to district administration (*Kecamatan*) and the villages were grouped into preparatory villages. However, in 1987, the *Kecamatan* was abolished and the villages, that had developed into communities, had to be abandoned for reforestation. Now, there are only three villages left and their fate rests with the decision of the government. The villagers in Sidorejo, Bandar Agung, and Brawijaya are constantly in conflict with the Regional Forest Office regarding the management of land for cultivation. The officers are in favour of relocating the villagers and using that land for reforestation and turning it into a protected area.

COMMUNITY PARTICIPATION IN SUSTAINING THE ENVIRONMENT

One of the basic questions this study tackles is that of community participation and the attitude of the three remaining villages (especially the Sidorejo village) in maintaining their environment. In-depth interviews and focus group discussions (FGDs) have been conducted among a number of respondents from these villages.

The results of the interviews and the FGDs indicate the readiness of the villagers to implement environmental programs, both for maintaining the forest areas and for planting multipurpose tree species. All that the government needs to do is to provide guidance on the types of trees to be planted. The villagers have shown a lot of enthusiasm towards the programs and are ready to commit themselves to them.

Therefore, the problems are not concerned with the willingness of the community to protect and sustain the environment, but with the uncertain status of its villages. There should not be any doubt about the Gunung Balak community's willingness to protect its environment (especially in the Sidorejo village). This can be observed from the eagerness of the community to support the development of social facilities. Therefore, it now falls on the government to formulate the necessary policy to accommodate community aspirations. This would ensure the preservation of the environment without sacrificing the interests of the community.

There have been cases of forest cutting involving both the government authorities, as well as the people from the community. According to these people, participation in this deforestation activity came from people outside the Gunung Balak area, and was initiated by government employees or forest rangers. The community confessed to there being some incidents of individuals gathering firewood from the forests. However, this did not entail cutting trees but collecting wood from fallen trees for the cooking purposes. It was later confirmed that a few small sonokeling (*Dalbergia Latifolia*) trees had fallen because of rotten roots.

Based on the above, and the fact that forest rangers and outsiders are often responsible for deforestation, the need to preserve and guard the forests has become a crucial issue. The mechanism to protect the forests should include the community that would need a channel to report their observations and findings. Some of the people even have photo documentation of illegal forest cuttings. The majority of the respondents have even volunteered their involvement in preserving forests. The decision to involve the community in conserving the forests will lessen the opportunities available to the forest rangers for working together with members of the community in cutting down the trees.

CONCLUSION

This section discusses the conclusions drawn from the above analysis.

1. The transmigration program, implemented in Lampung since 1972, has brought in considerable developmental progress to the province. Areas with difficult access have now become centres of development and growth. Another side-effect of the success of the transmigration program in Lampung is that it has attracted spontaneous migration into the province. The success in transmigration, however, has its negative effects by causing excessive pressure on the land, leading an imbalance between the population density and the carrying capacity of the land.
2. Population growth has also exerted increasing pressure on the land. Hectares of land that were formerly under forest cover have now been converted into farmland and settlement areas. According to the Provincial Forestry Office, forest cover has declined from 1 233 114 hectares to 817 093 hectares, a reduction of 416 021 hectares. Only 26.03% or 817 093 hectares of land in Lampung is now under protected forest cover. This is lower than the 30% required by the 1967 ACT No. 5 on forest laws. The picture becomes more dismal when we see that by 1990, this percentage fell to 22.97%.
3. The case of Gunung Balak demonstrates that environmental problems require more than just understanding and participation; they also need the incorporation of firm and consistent government policies. In a timespan of about 30 years (from the beginning of the 1960s to the end of the 1980s), government policies have repeatedly changed and are often contradictory. In the 1960s, the Regional Forest Office allowed people to cut down trees using the selective tree cutting method and to plant crops using the interplanting system. In 1974, the Gunung Balak region was promoted to District Administrative (*Kecamatan*) and the villages were grouped into preparatory villages. However, this was abolished in 1987 and the villages in the district were abandoned, giving way to reforestation programs. Now, there are only three villages in the area which await the decision of the government in deciding their fate.
4. Policies for the three remaining villages would need to consider the legal and sociological realities involved in reallocating the people of the community. Experience shows that a policy can be effective if, and only if, the aspirations of the people are built into the policy without detracting from the main purpose of conserving the environment.
5. The case of the remaining three villages in Gunung Balak are reminders of the conflict between the development and conservation of natural resources or reforestation. On the one hand is the need to protect the environment, and on the other, for continued development efforts.
6. From in-depth interviews and FGDs, it has been observed that the communities are willing to protect the environment and contribute towards the conservation of the forests. They are prepared to participate in the cultiva-

tion of perennial plants or multipurpose tree species. The role of the government here would be crucial as a guide and supervisor to the community, directing them on the types of plants that should be cultivated on their land.

7. Community perceptions on and participation in environmental conservation depend critically on the policies of the government and its ability to create a conducive environment. The community would then respond positively if their expectations are fulfilled by the government, and negatively, if the policies adopted are not in concurrence with the realities. Past experiences have displayed the sensitivity of communities towards government policies.

POLICY RECOMMENDATIONS

On the basis of the above case study, certain recommendations are proposed below.

1. Concerned government agencies need to intensively coordinate efforts for adopting necessary policies for the three villages. Present conditions seem to reflect that each agency is focusing on its own sectoral interest, disregarding the larger interests of the community. Interagency coordination is, therefore, necessary to bring together various interests for sustaining the environment, developing the area, as well as improving the welfare of the people in the three villages. Legal considerations should be adapted to the local conditions and the existing sociological realities.
2. It is also essential to reexamine the utilization of land, keeping in view the balance between the number of people and the carrying capacity of the land in every area (including the Gunung Balak area). Such considerations would enable the development of the area. Factors such as land mapping, according to its function; the maintenance of villages as agricultural areas, abandoning plans of relocation and reforestation; and the extent of development in keeping with the carrying capacity of the land need to be studied in order to ensure an integrated process of development.
3. It is important to motivate the people of the three villages to get actively involved in protecting the forests and the environment. Their willingness to participate in reforestation and in the preservation of forest lands, including the planting of trees with dual functions serving both hydrological and economical functions, needs to be analyzed and followed up with an integrated policy.
4. The alternative policies for the future of the remaining three villages also need to be examined and attempts should be made to achieve the following targets concurrently. First, the forest area should remain intact to pre-

serve the catchment area of the Way Jepara Lake. This problem, as mentioned earlier, emerged when a plan was made to build an irrigation system at Way Jepara Lake. The building of irrigation systems here would need to be reviewed. The decision of the Lampung Residency in 1935 would need to be understood in the context of sustaining Way Jepara Lake with its irrigation system. Second, ways should be devised to maintain the areas already developed. Developmental work should continue without causing harm to forest lands and ensuring the sustainability of the environment. In this way, the efforts of the government and the local people would not be wasted. Finally, such efforts should aim at improving or, at least, maintaining the present welfare level of the local tenants.

5. It would be possible to achieve these aims by actively involving the local people in the process of reforestation in their areas. The social forestry concept would probably be applicable in this area. This concept involves cultivating perennial plants called multipurpose tree species (MPTs), having dual functions – hydrological and economical – apart from horticulture, which has an economic value.
6. Continued public information activities through extension services need to be carried out to make the people aware of the importance of protecting the forest and preserving the environment. Community leaders in the three villages should be persuaded to get involved in this campaign.

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HUMAN POPULATION AND WATER: MEETING BASIC NEEDS IN THE 21ST CENTURY

Peter H Gleick[1]

INTRODUCTION

The Earth's limited freshwater sources are essential for every aspect of the survival and health of humans and the ecosystem. As human populations grow, economic, social, and military conflicts for water may well increase. In recent years, several analysts have expressed concern about growing water scarcity and contamination, and the likely inability of many governments to meet the water requirements of rapidly growing populations (Falkenmark, Lindh 1974; Postel 1992; Gleick 1993, Engleman, LeRoy 1993). This paper explores the connections between human population and freshwater problems, and proposes a new way of addressing them. In particular, the concept of sustainable water use is defined and discussed in the context of growing human populations, and a basic water requirement (BWR) for human needs is identified, quantified, and recommended. Evaluating access to this BWR may prove to be a more useful measure of human well-being than traditional water indices.

THE PROBLEM

Although the Earth is often called the 'water planet' because of the vast amount of water present, these resources are unevenly distributed in space, time, and type (see, for example, Shiklomanov 1993). 97% of all water resources is salt water, which is too salty to meet either drinking or agricultural needs Moreover, a sizable majority of the remaining three percent is locked away from human reach in the vast icecaps of Greenland and Antarctica and in deep groundwater aquifers. The small amount of freshwater that is techni-

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cally and economically accessible to humans is unevenly distributed in space and time; so unevenly that society spends billions of dollars every year either to: (i) channel water from wet to drier areas; (ii) to store it in wet seasons for use in dry periods; or (iii) clean otherwise undrinkable sources. These geophysical characteristics lead to a wide range of water-related problems, including interstate conflicts over access and quality, competition between urban, rural, and environmental uses, severe human health problems, and constraints on economic development.

Many basic human needs for water still remain unsatisfied. In 1990, nearly two billion people lacked access to clean drinking water and adequate sanitation according to the official UN definitions. Over a billion people throughout the world are served either by sewage treatment systems that do not measure up to the standards set by ancient Rome, or by no systems at all. The direct and indirect human costs of this are enormous and include extensive health problems, high labor costs (particularly for women forced to travel long distances each day to haul water to meet even the most minimal needs), and severe limits on the extent and form of economic development. As a result of the lack of clean water and sanitation services, there are billions of cases of water-related disease with over five million deaths every year (Warner 1995). Table 1 shows current estimates of water-related disease morbidity and mortality. Many of these health problems are getting worse. In 1991, a new cholera pandemic spread across Latin America, an area that had been free of cholera for more than 100 years. It now has more cholera cases than any other continent. Figure 1 provides a clear picture of the cases of cholera worldwide.

COMBINING POPULATION AND WATER ISSUES

Hydrologists typically measure water scarcity by looking at per-capita water availability or use; i.e., the water available or used in a region per person (Falkenmark, Lindh 1974; Engleman, LeRoy 1993). The average amount of water available per person in 1850 was about 43 000 m^3 per year. By 1990, this figure had dropped to 9000 m^3 per year, simply because of the increase in global population. When evaluated on a more detailed regional level, the distribution problems described above become even more apparent.

Figure 2 shows the large variations in current per-capita water availability for each continent – Oceania has over 70 000 m^3/person/year, the average for all of Africa is under 7000 m^3/person/year, while that of Asia is only 3400 m^3/person/year. Even greater disparities are noticeable if one looks at this problem at a national or regional basis. For example, Iceland, Norway, Canada, and New Zealand together get more than 100 000 m^3 of water per person per year, while some countries in Northern Africa and the Middle East have less than 100 m^3/person/year (Gleick 1993). Eastern US gets two or

Table 1. *Estimates of morbidity and mortality of water-related diseases*

Disease	*Morbidity (episodes/year)*	*Mortality (deaths/year)*
Diarrhoeal diseases	1000000000	3300000
Intestinal helminths	1500000000 (people infected)	100000
Schistosomiasis	200000000 (people infected)	200000
Dracunculiasis	100000 (people infected, excluding the Sudan)	—
Trachoma	150000000 (active cases)	—
Malaria	400000000	1500000
Dengue fever	1750000	20000
Poliomyelitis	114000	—
Trypanosomiasis	275000	130000
Bancroftian filariasis	72800000 (people infected)	—
Onchocerciasis	17700000 (people infected, 270000 blind)	40000 (mortality caused by blindness)

Source WHO (1995a)

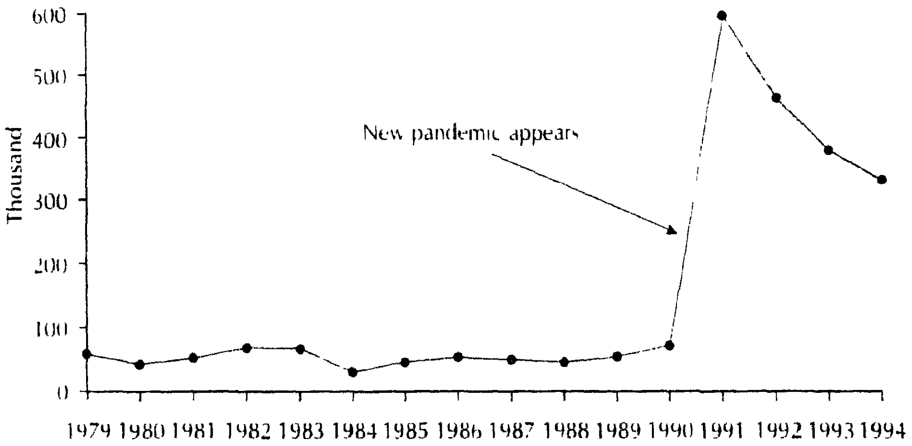

Figure 1. *Cholera cases worldwide*
Source. Data from WHO (1995b).

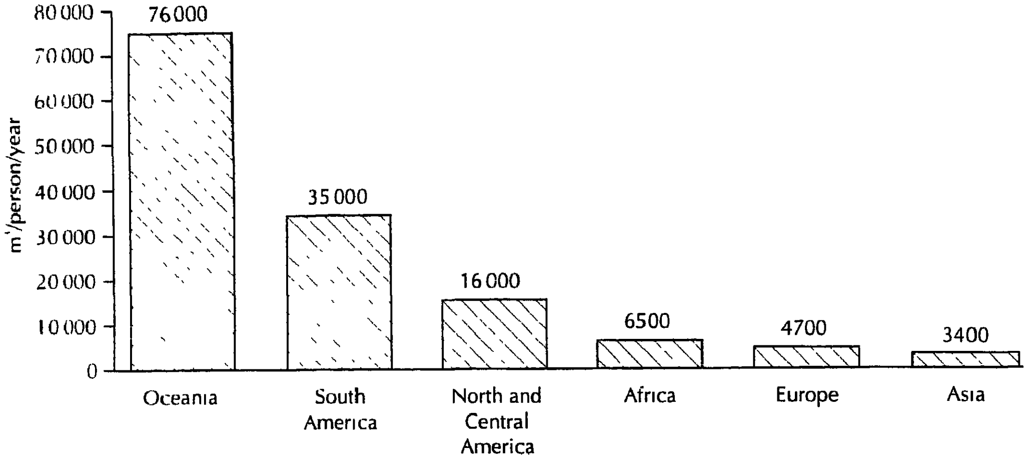

Figure 2. *Per capita water availability by continent*
Source. Data from Gleick (1993).

three times the amount of water per capita that what California gets, and many times the amount received by the arid region of southwestern US.

Just as physical water availability is unevenly distributed around the world, per-capita water use also varies widely for physical, economic, and social reasons. North Americans use over 1600 m^3/person/year, while the average in Europe is 725 m^3/person/year (Figure 3). In Africa, the average water withdrawal is under 250 m^3/person/year, reflecting the limited physical resources available, the large populations, and the poorly developed water-supply systems.

When the total amount of water available is relatively fixed, increasing population will reduce the total per-capita water availability over time. This simple observation has spawned substantial literature, ranging from the early work of Falkenmark, Lindh (1974) wherein regional water availability is compared to water demands under different population scenarios, to the more recent study of Engleman, LeRoy (1993; 1995 revision). The latter takes the national water availability data from Gleick (1993) and combines them with UN population projections till the year 2050 to highlight those regions where scarcity either already exists or is likely to develop in the coming decades.

Table 2 from Engleman, LeRoy (1995) shows the 1990 population living in regions facing water 'scarcity' and water 'stress', usually defined as regions with less than 1000 and 1667 m^3/person/year, respectively. Using UN low, medium, and high population projections, this table also shows how these levels of populations will increase up to the year 2050. If population growth is

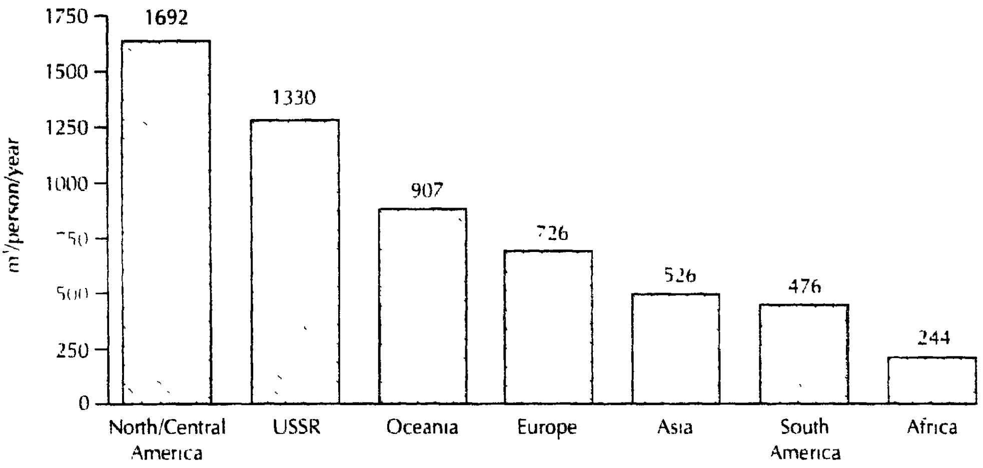

Figure 3 *Per capita water withdrawal by continent*
Source Data from Gleick (1993)

closer to the high population track than the low projection, 250 million additional people will be subject to severe water scarcity by the year 2025. By 2050, this figure would be nearly 1.4 billion.

Table 2. *Populations in water-scarce, water-stressed, and water-abundant regions (millions)*

UN projections	*1990*	*2000*	*2025*	*2050*
Low projections				
Scarcity[a]	132	277	653	1059
Stress[b]	206	270	2008	2446
Abundance[c]	4935	5521	4922	4390
Medium projections				
Scarcity	132	281	945	1928
Stress	206	273	2379	2458
Abundance	4935	5589	5057	5420
High projections				
Scarcity	132	285	904	2429
Stress	206	277	2591	5270
Abundance	4935	5657	5460	4179

[a] less than 1000 m^3/person/year availability, [b] less than 1667 m^3/person/year availability, [c] more than 1667 m^3 /person/year availability
Source Data from Engleman, LeRoy (1995)

There are some important limitations to these kinds of assessments. First of all, they are based on net water availability data for large areas. These data have some limitations: they usually do not include water for rainfed agriculture; they are often based on computed, and not measured, data (see Gleick 1993); they often include water either committed to riparian countries downstream or already used by a riparian neighbor upstream; and they hide important smaller regional differences.[2] For example, India, China, and the US, among other countries, have regions that are already facing extreme water shortages. Yet, average data for these countries do not reveal immediate problems (Engleman, LeRoy 1993).

Due to these limitations, the long-term goal of water planners must be to move beyond simple per-capita evaluations and to rethink the population and environment debate by helping to place population processes and water problems in their social, political, and economic settings. Some principles of sustainable water use are presented below, which may prove more useful for evaluating regional problems and for offering solutions. In addition, a new measure of absolute scarcity is presented: the population lacking access to a minimum water requirement for basic human needs.

PRINCIPLES OF SUSTAINABLE WATER USE IN THE 21ST CENTURY

Water is essential to sustain life, support ecosystems, and provide for economic development, community well-being, and cultural values. How are these varied benefits, which are sometimes in conflict with each other, to be prioritized? What is to be sustained? For how long? Who are the beneficiaries? In the context of freshwater resources, any discussion of sustainable development requires that we understand both the physical resources and the benefits or services that those resources must provide.

As described above, freshwater is widely and unevenly distributed around the world. The water available for use in any place, or by any group of users, is not constant, but varies widely over time and space due to both natural fluctuations in the global hydrologic cycle and the nonnatural fluctuations caused by human interventions. In the absence of human interventions, natural ecosystems have evolved and adapted themselves to these natural hydrological fluctuations. The imposition of human systems often alters both the natural hydrologic regime and the ecosystems that depend upon them.

Using the per-capita measures described above, any increase in population will lead to a decrease in per capita water availability, which is usually assumed to be bad. A better definition of sustainable water use is the 'maintenance of a desired flow of specified *benefits* to a particular group, undiminished over time'.[3] Refining this further requires that the sustainability of some set of benefits be maintained without affecting the ability to provide comparable benefits into the future to all groups – similar to the more general and widely quoted definition developed during the work of the World Commission on Environment and Development (WCED 1987).

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[2] Engleman, LeRoy (1993) are aware, and discuss many, of these limitations in their report. However, approaches for dealing with many of them have not yet been adequately developed.

The desired set of benefits provided by water is unlikely to be the same across different users or periods of time. Indeed, such benefits vary widely, given political, religious, cultural, and technological differences. Using the definitions above, water use is unsustainable if the services provided by water resources and desired by society diminish over time. Equity requirements would also require that a reduction of services over time to one user group be declared 'unsustainable' even if other users are able to maintain their desired services.

There are two ways in which unsustainable water use can develop: through alterations in the stocks and flows of water that change its availability through time; and through alterations in the demand for the benefits provided by a resource because of changing standards of living, technology, population levels, or societal mores.

The first factor – water availability – is affected by both natural and anthropogenic factors, including climatic variability and change, population growth that reduces per-capita water availability, contamination that reduces 'usable' water supplies, physical overuse of a stock such as groundwater overdraft, and technological factors. Similarly, the second factor – water demand – is not constant, increasing with growing populations, changing as social values and preferences change, and increasing or decreasing with technological innovation and change.

Sustainable water use also involves the institutions that control the distribution of water in space and time. Social systems to manage water resources must be capable of coping with changes in supply and demand, and in responding to varying priorities of water use under different conditions. Given all these issues, a working definition of 'sustainable water use' was developed by Gleick *et al.* (1995)

> *...the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it.*

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[3] Note that there is a difference between water use and the benefits of water use. There are several ways in which declining water use can occur without a decline in the benefits of water use, such as through improved efficiency of use. This distinction is often ignored by water analysts.

This definition of sustainable water use provides an arching framework by which decisions about human water use can be judged. By itself, however, it is too general to offer guidance for water managers, planners, and scientists. In order to make decisions about how to allocate and use water resources, other goals and criteria need to be identified. Explicit criteria and goals for the sustainability of freshwater resources are presented in Box 1. These criteria lay out human and environmental priorities for water use, taking into account not only the needs of the current populations, but also those of future generations.

These criteria and goals are the result of considerable dialogue and analysis with academic, governmental, and nongovernmental interests working on regional, national, and international water problems. They are not, by themselves, recommendations for actions; rather they are endpoints for policy – they lay out specific societal goals that could, or should, be attained. In particular, these criteria can provide the basis for alternative 'visions' for future water management and can offer some guidance for future legislative and nongovernmental actions (Gleick *et al.* 1995).

WATER AND POPULATION: A NEW APPROACH

The first criterion in Box 1 deserves special mention in the context of growing populations. As stated, all humans should be guaranteed access to sufficient

Box 1. *Sustainability criteria for water*

- Minimum water requirements will be guaranteed to all humans essential for the maintenance of human health.
- Sufficient water will be guaranteed to restore and maintain the health of ecosystems. Specific amounts will vary depending on climatic and other conditions. Setting these amounts will require flexible and dynamic management.
- Water quality will be maintained to meet certain minimum standards. These standards will vary depending on location and how the water is to be used.
- Human actions will not impair the long-term renewability of freshwater stocks and flows.
- Data on water resources availability, use, and quality will be collected and made accessible to all parties.
- Institutional mechanisms will be set up to prevent and resolve conflicts over water.
- Water planning and decision-making will be democratic, ensuring representation of all affected parties and fostering direct participation of affected interests.

Source. Gleick *et al.* (1995)

water to maintain human health, independent of the size of the population. The concept of meeting basic human needs has been advocated in several different international environment and development fora, including the 1977 Mar del Plata conference – one of the earliest international efforts to address global water problems.

> *...all peoples, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs* (UN 1977).

This concept was strongly reaffirmed during the 1992 Earth Summit in Rio de Janeiro and expanded to include ecological water needs

> *In developing and using water resources, priority has to be given to the satisfaction of basic needs and the safeguarding of ecosystems* (UN 1992).

Gleick (1996) defines and quantifies BWRs for four basic human needs – the supply of freshwater that is quantitatively *and qualitatively* sufficient to provide minimum drinking water for survival; and water for sanitation services, bathing, and modest household needs for cooking and cleaning. The recommended levels of BWRs is shown in Table 3. Gleick (1996) recommends that international organizations and national and regional governments adopt a standard of 50 liters per person per day (l/p/d) of clean water and guarantee access to it independent of economic, social, or political status. Unless this basic need is met, large-scale human misery and suffering will result and will continue to grow in the future.

Table 3. *Recommended BWRs for basic human needs*

Purpose	*Recommended BWRs*[a] *(l/p/d)*
Drinking water[b]	5
Sanitation services[c]	20
Bathing	15
Cooking and kitchen	10
Total recommended BWRs	50

[a] Excluding water required to grow food (see Gleick 1996) These quantities must also be of the minimum quality essential to prevent water-related diseases, [b] This is a true minimum to sustain life in moderate climatic conditions and with average activity levels, [c] An average (not minimum) of 40 l/p/d is considered adequate for direct sanitation hookup in industrialized countries In extremely water-short regions, sanitation systems that use no water are available, but are rarely accepted socially.

Using this measure of providing 50 l/p/d of clean water, it is possible to evaluate the size of the population lacking access to the basic requirements for even a minimally satisfactory quality of life. Vast regions of the world and hundreds of millions of people lack the water required to meet the basic human needs proposed above. Table 4 lists those countries of the world whose average domestic per-capita water withdrawals, as reported to the UN and other organizations, fail to provide a BWR of 50 l/p/d. According to 1990 data, 55 countries and nearly a billion people fell below the amount recommended in this paper.

There are actually eight countries whose total reported water use in *all* sectors falls below the recommended BWRs for just basic human needs. While, in some cases, this may reflect problems in reporting actual water use, it also reflects the dire resource conditions in the larger regions of Africa, Asia, and Central America. Furthermore, population growth is increasing in most of these regions faster than improvements in water supply.

Table 4. *Countries with total domestic water use below 50 l/p/d*

Country	*1990 population (millions)*	*Average domestic water use (l/p/d)*	*Domestic water use as a percentage of the BWR of 50 l/p/d*
Gambia	0.86	4.5	9
Mali	9.21	8.0	16
Somalia	7.50	8.9	18
Mozambique	15.66	9.3	19
Uganda	18.79	9.3	19
Cambodia	8.25	9.5	19
Tanzania	27.32	10.1	20
Central African Republic	3.04	13.2	26
Ethiopia	49.24	13.3	27
Rwanda	7.24	13.6	27
Chad	5.68	13.9	28
Bhutan	1.52	14.8	30
Albania	3.25	15.5	31
Zaire	35.57	16.7	33
Nepal	19.14	17.0	34
Lesotho	1.77	17.0	34
Sierra Leone	4.15	17.1	34
Bangladesh	115.59	17.3	35
Burundi	5.47	18.0	36
Angola	10.02	18.3	37
Djibouti	0.41	18.7	37

(Continued...)

Table 4. *(Continued)*

Country	*1990 population (millions)*	*Average domestic water use (l/p/d)*	*Domestic water use as a percentage of the BWR of 50 l/p/d*
Ghana	15.03	19 1	38
Benin	4 63	19.5	39
Solomon Islands	0 32	19 7	39
Myanmar	41 68	19.8	40
Papua New Guinea	3.87	19.9	40
Cape Verde	0.37	20.0	40
Fiji	0.76	20 3	41
Burkina Faso	9.00	22.2	44
Senegal	7 33	25.4	51
Oman	1 50	26.7	53
Sri Lanka	17 22	27 6	55
Niger	7 73	28 4	57
Nigeria	108 54	28 4	57
Guinea-Bissau	0 96	28 5	57
Vietnam	66.69	28 8	58
Malawi	8 75	29 7	59
Congo	2.27	29.9	60
Jamaica	2.46	30.1	60
Haiti	6.51	30.2	60
Indonesia	184.28	34.2	68
Guatemala	9.20	34.3	69
Guinea	5.76	35.2	70
Cote D'Ivoire	12.00	35.6	71
Swaziland	0.79	36.4	73
Madagascar	12.00	37.2	74
Liberia	2 58	37.3	75
Afganistan	16 56	39 3	79
Uruguay	3 09	39 6	79
Cameroon	11.83	42 6	85
Togo	3.53	43 5	87
Paraguay	4.28	45.6	91
Kenya	24.03	46.0	92
El Salvador	5 25	46.2	92
Zimbabwe	9.71	48.2	96

Source Gleick (1996)

In contrast to these figures, domestic water use in all industrialized countries far exceeds the BWR, though the quality of this water varies widely. In the countries of western Europe, the recommended BWR is typically less than

25% of total domestic use. In the US and Canada, a BWR of 50 l/p/d is less than 10% of total domestic use, reflecting the much greater availability and use of water in homes.

There are strong reasons to believe that the number of people failing to receive the recommended BWR is actually far above the numbers reported here. The data in Table 5 are country averages, and several large countries, such as India and China, report that their average domestic water use only marginally exceeds 50 l/p/d. We know, however, that average national water use data hide significant regional variations, with large segments of populations usually falling below the average, while the wealthier portions of the population tend to use far more per capita. An additional problem is that there are few data to indicate the typical *quality* of the water received. The domestic water quality level is a severe and widespread problem, and it is likely that many people who may receive more than the recommended quantity receive contaminated and unhealthy water.

THE ROLE OF DIFFERENT POLICIES IN REDUCING WATER STRESS

Two problems deserve special attention: (i) increasing populations that lead to both decreasing per-capita water availability and increasing overall demand; and (ii) changing conditions (particularly technology and climate) that affect both water supply and demand. In the first case, assuming constant levels of total water availability, increasing populations lead directly to decreasing per-capita water availability and pressures on the levels of benefits or the mix of benefits that water provides. Ultimately, unlimited population growth must lead to decreasing water availability, the reallocation of water from one user or sector to another, the unsustainable 'mining' of nonrenewable stocks of water, and, in the end, decreasing overall human well-being.

In the second case, technological developments can alter water availability and affect levels of water required to satisfy demands. In theory, practically unlimited quantities of freshwater are available by mining water currently trapped in glaciers and icecaps, or on an even larger scale, through the mass desalination of sea water. In practice, however, increases in overall water supply will occur only where the value of water exceeds the economic and environmental costs of supplying that water through new technology.

The other basic assumption – that overall water supply is fixed – is now being challenged by the problem of global climatic change. As evidence accumulates that climatic changes are a serious concern, hydrologists and water managers must rethink old assumptions about the reliability of supply. While total water availability has always been stochastic, existing systems are designed and built to accommodate that known variability. However, some of the largest changes expected from the greenhouse effect will be associated with the hydrologic cycle and water availability (Schneider, Gleick, Mearns 1990; IPCC 1992; 1995).

THE FALLACY OF ADDRESSING POPULATION IN ISOLATION

Some analysts address water problems, or, indeed, any resource problem, by addressing population alone. Their argument, to put it in its most simple form, is that fewer people will place less pressure on scarce and finite resources. This argument is certainly true, as far as it goes, but it does not go far enough. Population growth rarely, if ever, acts alone to produce water scarcity, and looking at it in isolation shifts attention from policies that may be equally or more effective in reducing human misery. By ignoring the related roles of consumption levels, the form of resource use, and the role of economics, technology, and culture, such an approach often ignores many of the most important and effective policies for solving problems. Population, human welfare, and water availability and use must be considered as dimensions of the same complex problem.

But, how effective would other factors be in altering water needs? Society is constantly making conscious and unconscious decisions that affect demand and supply of water. Some of the factors worth looking at include improvements in the efficiency of water-using technologies, new technology for water use, changes in life-styles and personal preferences, different agricultural policies, and so on. The effectiveness of a few of these alternatives are explored below.

Improvements in Water Use Efficiency

Studies are only now being initiated on the potential for extensive water efficiency improvements. The least work has been done in developing countries in the agricultural and domestic sectors – paralleling the problems in quantifying potential energy efficiency improvements in the 1970s and the 1980s.

A good example of this is Egypt, which is entirely dependent on the river Nile for its water, 97% of which originates outside Egypt's border. Egypt is already reaching its limits of water supply. Due to its limited options for new supply, efforts are being made to improve the efficiency of Egypt's agricultural and urban sectors. Additionally, Egypt faces the problem of a high and rapidly growing population. This combination is already causing water stress throughout the country. Figure 4 shows how total water demands would rise under the medium and low UN population projections through the year 2025 if the per-capita water use remained constant. As this figure shows, the difference between the two population scenarios is quite small, suggesting that even extensive population policies would not be of much use in solving Egypt's water problem.[4]

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[4] This is in no way an argument against implementing extensive population policies – there remain many other substantial benefits in implementing such policies. Rather it suggests that the rationale for such policies must come from their impact on other critical social, economic, and environmental problems.

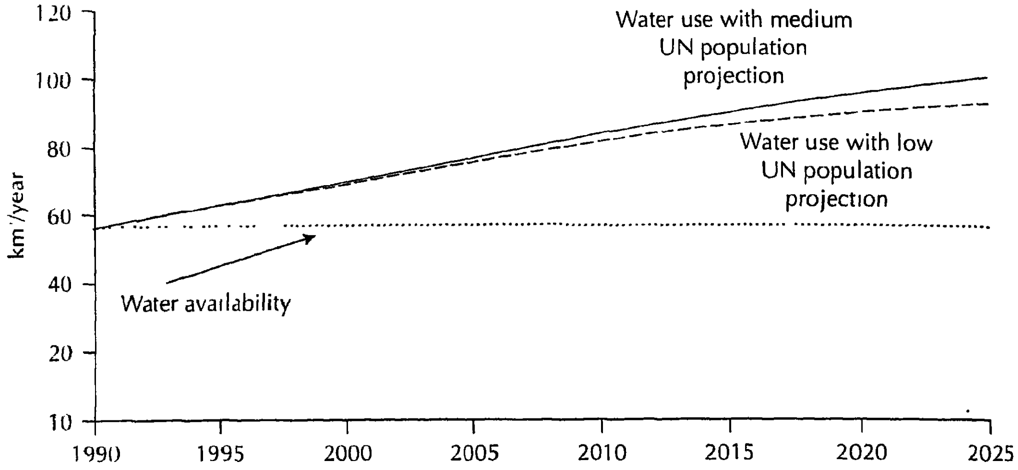

Figure 4. *Water use in Egypt: low and medium population projections*

In reality Egypt is, of course, unlikely to reach even this level of water use because of absolute constraints on availability. In the absence of inexpensive desalination, its only alternative is, to decrease per-capita use of water. This can happen in two startlingly different ways: with *declining benefits* resulting from continued inefficient use of water in traditional ways; or with *constant or improving benefits* resulting from improving water-use efficiency and changing water policies.

With no change in water allocations, the efficiency of water use, or water management, growing populations will lead to a straightforward decline in per-capita use of water and a comparable decrease in agricultural output, industrial productivity, and human well-being. If, however, efforts are made to reallocate water from inefficient users or to improve the efficiency of current uses, it is possible to maintain or even increase productivity and well-being with a constant, absolute amount of water. Figure 5 shows how total water demands would be affected by annual improvements in water-use efficiency of only one percent per year, a number considered by many to be both plausible and achievable (Abu-Zeid, Seckler 1992), particularly if agricultural policies are permitted to change. In this case, using the medium UN population projections, total per-capita water demands drop more than 20%. In a country like Egypt, where per-capita water use is relatively high because of large irrigation withdrawals, substantial changes in water use are possible without threatening basic human needs.

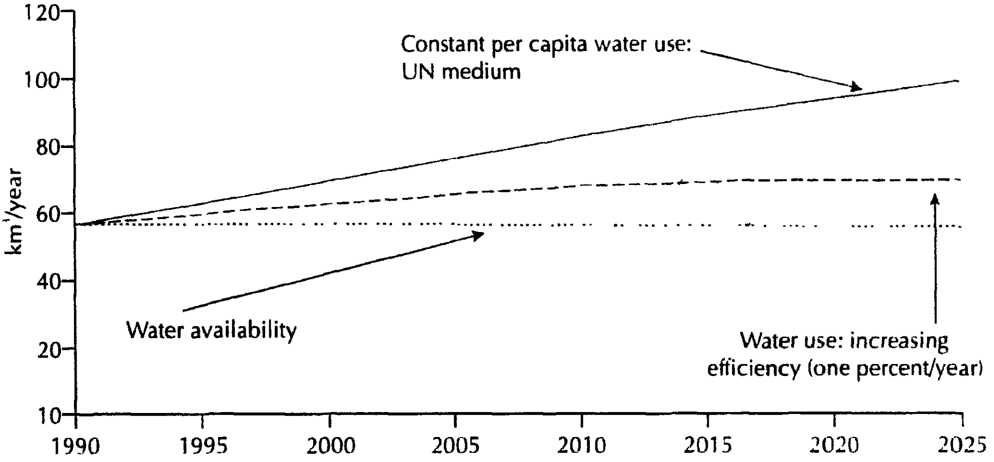

Figure 5. *Water use in Egypt. changes in water use efficiency*

CONCLUSIONS

If we cannot solve the population problem, we ultimately face declining per-capita water availability and use, and eventually, declining quality of life and benefits. As a result, policies to reduce rapid population growth in water-short regions are necessary and urgently needed. However, such policies cannot, and should not, be the only approaches taken to address water problems. Indeed, in the short run, they may not prove to be the most effective, equitable, or just.

In the near term, policies to reduce population growth (short of intensely repressive policies or some severe health crisis) will not be sufficient to prevent serious water-related problems from getting worse, particularly human health problems, ecological disasters, and interstate conflicts. In addition, reducing the population growth rate, even to zero, is no guarantee that sustainable and equitable water use will result. This is a classic case of something that is necessary but not sufficient. Even in a zero population growth situation, society can still have social inequities, contamination of water supplies, intentional manipulation of water, political conflict, and loss of aquatic ecosystems, unless these problems are directly and quickly addressed.

A new way of thinking about the long-term sustainable use of water is to focus on meeting basic human and environmental needs for water. The definition of sustainable water use presented here, together with the proposal to satisfy the BWRs for all humans, should help water planners set explicit goals for water supply. Ultimately, decisions about defining and applying this concept of a BWR will be based on political and social factors, but the concept may prove useful in meeting basic water needs for the next century.

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THE LONG, DARK SHADOW: POPULATION, WATER, AND PEACE IN THE MIDDLE EAST

Thomas Naff[1]

INTRODUCTION

A few years ago, Paul Demeny of the Population Council in New York declared that the world's hydrological conditions are dwarfed by demographic changes (Demeny 1991). Whatever the accuracy of that statement, it does have the virtue of focusing one's mind on the conjoined issues of water and population. For all societies, the volume, quality, and adequacy of water supplies are governed by climate, ecology, and the environment, in combination with the size of population, its distribution, and economic activity. Everywhere, the way in which these factors intermingle determines the quality of life. The interactive consequences of overpopulation and water problems have become virtually universal, no more so in any part of the globe than in the Middle East which is, in many ways, a microcosm of the most alarming aspects of the world's population explosion.

To understand just how vestigial is the margin of safety for humanity and all other living organisms that depend on fresh water for their existence, imagine that the earth's total supply of water amounts to one cubic meter; then of that single cubic meter, the usable volume of fresh water not locked in ice would amount to a mere five teaspoons. Humankind is in competition for those figurative five teaspoons with other life forms essential to its survival; if they disappear for lack of water, so too will human beings. As the world's population increases and per capita income rises, demand for more water grows accordingly, placing greater stress on stocks that are already minuscule, maldistributed, and rapidly diminishing. Fortunately, most of the planet's fresh water supply is renewable and can be supplemented (in as yet very lim-

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ited quantities) by such technologies as desalination, and if the supply is not consumed more rapidly than it can be replenished, and if it is used rationally, cooperatively, and efficiently, calamity may be avoided. However, it is the demographics of the future that will determine success or failure for humankind (Table 1).

The Middle East has, historically, been of great geopolitical importance to the West and, today, with its huge oil reserves, constitutes a vital strategic and economic interest for the industrialized world. Therefore, any event or situation that menaces the stability of the region is of intrinsic concern to our interdependent planet – as demonstrated by the swiftness with which an alliance was formed to oppose Iraq's invasion of Kuwait. The potential threat posed by the rapid upward spiral of population expansion in the Middle East, with its scarce water resources, has created a situation of multifaceted complications very difficult to resolve and fraught with potential disaster.

Understanding the nature of the region's demographic problems is prerequisite to devising strategies for avoiding or managing hydrodemographic disasters. As the phenomenon of rapid population growth is worldwide and its consequences interconnected across regions, placing the Middle East's hydrodemographic problems in a global context provides an essential perspective on that region.

THE GLOBAL CONTEXT OF HYDRODEMOGRAPHIC ISSUES

It is widely agreed among demographic experts that the decade of the 1990s may well be decisive in settling the future of this planet as a habitation for humankind.[2] Decisions will be made that determine whether there will be only two rather than three times more people before population growth ceases, and whether the rate of damage to the earth's environment, which is the inexorable consequence of the existence of living creatures, will be faster or slower. What is certain is that in the next half century the largest and most rapid demographic increases (90%) will occur in the world's poorest countries (some of which are in the Middle East), those least able to provide for the newly created generations or invest in their future. Most of that growth will occur in the world's urban centers, many of which are already overcrowded, overused, underbudgeted, polluted, sprawling, with large pockets of squalor accompanied by inadequate housing and public health facilities, homelessness, and where the increasing gap between the 'haves' and 'have-nots' is most glaring. The world's population is growing by about 95 million

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[2] Sadik (1990: 1–28) summarizes key sections of the following UN publications: UN Population Division (1988; 1989); see also World Bank (1984; 1989); WRI (1989); and Repetto (1989).

Table 1. *Dynamics of global water use by humans*

Water users[a]	*1900 (km³/ year)*	*1940 (km³/ year)*	*1950 (km³/ year)*	*1960 (km³/ year)*	*1970 (km³/ year)*	*1975 (km³/ year)*	*1980*		*1990*[b]		*2000*[b]	
							km³/ year	(%)	km³/ year	(%)	km³/ year	(%)
Agriculture												
Withdrawal	525.0	893.0	1130.0	1550.0	1850.0	2050.0	2290.0	69.0	2680.0	64.9	3250.0	62.6
Consumption	409.0	679.0	859.0	1180.0	1400.0	1570.0	1730.0	88.7	2050.0	86.9	2500.0	86.2
Industry												
Withdrawal	37.2	124.0	178.0	330.0	540.0	612.0	710.0	21.4	973.0	23.6	1280.0	24.7
Consumption	3.5	9.7	14.5	24.9	38.0	47.2	61.9	3.2	88.5	3.8	117.0	4.0
Municipal supply												
Withdrawal	16.1	36.3	52.0	82.0	130.0	161.0	200.0	6.0	300.0	7.3	441.0	8.5
Consumption	4.0	9.0	14.0	20.3	29.2	34.3	41.1	2.1	52.4	2.2	64.5	2.2
Reservoirs												
Withdrawal	0.3	3.7	6.5	23.0	66.0	103.0	120.0	3.6	170.0	4.1	220.0	4.2
Consumption	0.3	3.7	6.5	23.0	66.0	103.0	120.0	6.2	170.0	7.2	220.0	7.6
Total (rounded off)												
Withdrawal	579.0	1060.0	1360.0	1990.0	2590.0	2930.0	3320.0	100.0	4130.0	100.0	5190.0	100.0
Consumption	417.0	701.0	894.0	1250.0	1540.0	1760.0	1950.0	100.0	2360.0	100.0	2900.0	100.0

[a] Total water withdrawal is shown in the first line of each category, consumptive use (irretrievable water loss) is shown in the second line, [b] Estimated
Source Gleick (1993)

people a year. By 1998, there will be about 6 billion people, 8 billion by 2020, and, if current growth trends continue, before the middle of the next century, the number will increase to 10 billion. One-fifth of the earth's 5.5 billion inhabitants receive 82.7% of the world's total income; the poorest one-fifth get 1.4% (UN 1992).

As humans multiply, they are literally consuming the earth at an alarming rate. Indeed, a waxing human population and the increasing per capita consumption of resources by humankind now constitute the primary source of pressure on natural resources (Johnston 1988). This incessant growth has already inflicted many harmful, often permanent, changes on the environment, particularly the depletion and degradation of land and water resources, as well as massive deforestation. One serious consequence has been an actual decline by 1.9% a year of available arable land per capita throughout the decade of the 1980s, a trend that has carried over into the '90s and is projected to continue into the next century.

As water, cropland, and population are inseparable, the negative effects of such losses on long-term fresh water supplies are obvious and real. Currently, total global cropland is estimated to be about 1.5 billion hectares. The most optimistic projections of arable land assume an approximate possible total of between 3.2 and 3.4 billion hectares. However, just about all of the best soil is already tilled. The remainder, which makes up the bulk of the latter forecast, is already 'either less fertile, insufficiently rainfed or easily irrigated, infested with pests, or harder to clear and work' (Homer-Dixon 1991a: 22; WRI 1990: 5–6; Sadik 1990: 8).

This combination of circumstances – declining water supplies and cropland together with rising, unsustainable rates of population growth – is striking in certain parts of the world, such as the Middle East, China, South Asia, and parts of Africa, that are known to be ecologically vulnerable and to suffer resource inequities. A country is said to experience land scarcity when 70% or more of its potential cropland is cultivated. Presently, without a substantial increase in arable land, the per capita average of cropland worldwide will drop from 0.28 to 0.17 by 2025 should the current rate of population growth continue.

Nearly 73% of all rural households in developing countries are landless and nearly a billion rural dwellers (exclusive of China) have too little land to provide subsistence levels of food and fuel. Were China taken into account, the numbers would increase by 100–200 million people. The world loses to erosion between 2 to 3 million hectares of cropland a year, with twice that amount lost to urbanization and another million or so to excess salinity due to water scarcity, poor management of land and water, and misuse of chemical fertilizers. Moreover, one-fifth of the earth's cropland is in some stage of desertification. At these rates of loss, the world's arable land will decrease by 100 million hectares by the year 2000.

As the factors that deplete croplands are interactive, their effects tend to ramify. A simple example is what can occur when even a single basic factor such as water is reduced or shifted away from croplands: there is a decrease in cropped acreage, changes in cropping patterns and practices must be made, degradation of soil (and perhaps the beginning of a process of desertification) ensues, or farming ceases altogether. In agriculture, these impacts may further unfold in a variety of other areas, e.g., water quality and quantity, land quality, community well-being, social institutions, and commodity flows at local, national, and international levels (White 1984: 474–475).

In the same way that a key ecological change in the pattern of soil usage can trigger developments that impact widely, so too does the factor of human induced change function in regard to renewable resources that are vital to the existence of humanity. Most renewable resources are inseparable parts of very complex, dynamic natural systems in which the effects of overexploitation of one basic unit can suffuse the entire system. Thomas Homer-Dixon of the University of Toronto offers us a convincing example

> *Forests, for example* (he writes), *not only provide wood for fuel, construction, and paper. They also reduce the variance in the hydrological cycle by slowing the runoff of rainwater and by absorbing and releasing some of it through transpiration; they stabilize soils and reduce erosion; they absorb and fix atmospheric carbon dioxide that otherwise might contribute to global warming; and they provide a habitat for diverse organisms. In turn, each of these renewable services helps sustain other goods and services in the ecological system. Thus the loss of forests can generate much more than just scarcity of wood: it can also generate scarcities of soils, of rainfall, of sustained and manageable river flow for hydropower and transportation, and of reservoir and irrigation capacity (since these systems become plugged with silt). If forest loss is widespread enough, it can diminish the biodiversity we need for our medicines and industries, and it might boost climate change. Some of these problems will induce yet other shortages: for instance, the silt that washes into the sea can smother coral reefs and thereby damage local fisheries* (Homer-Dixon 1995: 595).

The total number of people defined as poor by the United Nations (UN) now constitutes about one-quarter of the world's population. Population growth has vastly outpaced the resources needed for governments in developing or poorer nations to provide basic services to their citizenry. For example, urban households without safe water rose from 138 million in 1970 to 215 million by the end of the 80s, and in the same period, households lacking adequate sanitation leapt from 98 million to 340 million.

Another consequence of the expanding gap between the planet's swelling population and such finite vital natural resources as water and soil has been the creation of what has been labeled 'ecological marginalization'. Burgeoning numbers of poor people who are able to do so are migrating from wasted, dried-up lands to fertile grounds or to the margins of cities where they seek new forms of livelihood, thereby fueling the surge of urban sprawl in all parts of the world. This movement of populations binds, ever more tightly, environmental and resource degradation with intractable poverty, especially in regions with brittle environmental conditions, with the result that 'the world's poorest people are, thus, increasingly clustered in two types of areas: remote and ecologically fragile rural areas, and the edges of growing urban areas' (Leonard 1989: 5; Homer-Dixon 1991a: 34–35; Carruthers, Vining 1985).[3]

Overpopulation produces multiple threats to ecological sustainability, a susceptibility to scarcities of water and food, and, thus, to famine. Empirical evidence indicates that across the globe in nations where populations are high and per capita incomes are low, those societies lack the capacity to respond effectively to the consequences of that condition by reorganizing existing institutions or creating new coping mechanisms – particularly if at the same time there is a scarcity of such vital natural resources as water. These same societies tend to be deeply traditional; for them, change is difficult and slow, and, short of harsh coercive measures, they would find it very hard to stem – let alone reverse – the tide of population growth long enough for a new institutional order to take root. But it is possible, as we shall see.

SCALES OF TIME AND MASS

One of the hallmarks of the 20th century has been the sheer scale of its multilayered, interactive demographic and environmental problems – a scale and complexity that has set it off from any previous epoch. In the past, humankind has been stunningly inventive in finding solutions to the long spectrum of its problems. However, now, and into the foreseeable future, it can no longer be comfortably assumed that the alleviating fruits of human ingenuity will be available quickly enough, with enough equity and uniformity to all societies in time to stave off potentially widespread disaster. Biotechnical advances reach the poorest, most needy nations last. These are societies where virtually all the necessary skills, not to mention wealth, are very thin or absent, and where problems are so deep and population growth so rapid, that little progress toward a solution is made even with the help of technology.

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[3] Homer-Dixon (1991a) sees population growth as the 'forcing factor' of environmental damage, the most swiftly and dangerously changing variable in the environmental social system.

As biotechnology requires very high and complex levels of science, the lead times to proven results and widespread application are necessarily much longer than poor nations, already crisis-ridden with the bulk of the world's population, can bear. Moreover, given the magnitude, difficulty, unpredictability, and multifarious nature of population-driven problems, it is certain that a whole series – perhaps many series – of significant biotechnical feats will be required before widespread easement comes (Homer-Dixon 1991a: 10) Although the world, as a whole, may not be facing a ruinous fate in the immediate future, for many individual nations – many in the Middle East – the race between population growth, resource scarcity, and social and technical ingenuity will grow more desperate, and failure will appear more imminent. An unbounded faith that humanity will somehow produce answers to all of nature's uncountable processes would seem to be unwarranted. Whatever the level of wealth or poverty, technology, or competence, in any given place and circumstance, the larger the population, the greater the effects on the environment and resources.

Population and resource issues involve not only a scale of mass but a scale of time as well. Over time, even a relatively short span of time, the increase in absolute numbers of people could overwhelm present biotechnical solutions or render useless those in planning or experimental stages. It is a demographic axiom that at the current yearly average growth rate of some two percent, the world with its finite resources and diminishing fresh water supplies and quality cropland will double its population about every generation. As indicated, one of the more serious implications of such rapid growth is that there is no longer a sufficient margin of time for societies, particularly the more destitute, to adapt to the new absolute numbers before the cumulative negative effects of the increase make their impact. Furthermore, ecological processes such as desertification or long-term climatic swings and trends in precipitation, which tend to be interlinked with many other environmental mechanisms in complicated ways, operate on a time horizon so long as to be beyond the vision of the land users (who are frequently the victims of environmental changes) or their governments. In this context, it is worth noting that governments notoriously 'tend to intervene late, inadequately, or ineffectively' (Mortimer 1989: 4–6; White 1984: 477–478).

In these circumstances, even if the rate of change were to hold more or less steady, it is the absolute numbers rather than proportions, ratios, or percentiles that matter most. Any of the aforementioned data attest to this fact. Even a small percentile alteration of either growth or decline can result in an order of change amounting to hundreds of millions in absolute numbers. For example, fertility in India and Pakistan had fallen from six children per woman to 5.3 between 1975–80; but the rate of fall decreased between 1980–85 to only 5.1 – an apparent insignificance in percentiles and time. However, in absolute numbers, if there were to be no change, it means that by

2005 India will have acquired another 216 million people (only a little less than the present population of the US) and Pakistan's population will have risen by 57 million (just about equal to Egypt's current population; see Sadik 1990: 9). An increase from, say, 1–2 billion, at any given time, represents an increase by a factor of only one; but suppose the rise is from 5–10 billion, then the absolute increment is five times more.

Obviously, if the world's population remains on its present trajectory, the implacable number of new bellies that will have to be filled with food and water in a relatively short time will be immense. As the earth's inhabitants multiply at what are arguably unsustainable rates while universally demanding higher living standards, the need for worldwide intensification and expansion of agriculture will be greater than ever. Satisfaction of this need will require a sizeable increase of irrigation which is indispensable in arid, semiarid, and temperate zones (which include the Middle East); this, in turn, will require significant accretions of fresh water globally, and more rapid development in the fields of hydro and biotechnology. When large-scale calamity does afflict the most populated, vulnerable nations, the combination of massive numbers and lack of resources means that technology alone can rarely effect a rescue, not only because of the depth and difficulty of the problems, but because many other complex, interlaced policy- and decision-making issues are involved: political, ideological, cultural, religious, attitudinal, economic, psychological, social, strategic, and sometimes epidemiological.

The process of development in many nations has ineluctably exposed local agricultural production to the macroeconomic forces of the global market. When this circumstance is coupled with demographic pressures for more production, but without commensurate increases in productive capacity, resources, or technology, serious consequences ensue: for example, the traditional equilibrium among population, natural resources, and established institutional systems is often irreparably disrupted and 'unreplaced' by a new balance, frustrating the achievement of developmental goals (the Middle East, Sudan, Somalia, and Ethiopia illustrate this point). This is attested, in part, by a marked fall in the proportion of the labor force in agriculture. Rural to urban migration has, for decades, depleted the agricultural labor force, while the remaining landless workers and farmers migrate seasonally. The result, in some parts of the world, is that the rural labor force is becoming increasingly female and elderly (TAC Sec't, ICARDA Review 1989: 9).

POPULATION STRESS AND CONFLICT

The causes of conflict and war are complex and dynamic – involving such factors as an imbalance among demographic, economic, environmental, ecological, and political variables, as well as cultural values and attitudes toward aggression. There are many components to conflict which are, in themselves, syntheses of other concepts and must be taken into account in the construction of a working definition: security, values, ideologies, symbols, motivations, goals, and origination and processes of conflict. Conflict is basically the product of disagreement and/or disharmony that generates struggle, physical or otherwise, between opposing forces. Implicit in conflict is the governing factor of power in its various guises, and the element of frustration. Not all conflicts are violent, that is, violence need not be involved for there to be conflict; in fact, conflict can exist in a latent state until animated by any action, event, or situation (such as scarcity and population pressure), or by the perceived frustration of a need (Frey 1993:1; Coser 1956; Blalock 1989).

The demographic and resource components of conflict are intertwined; they often inspire perceived needs for access to more resources and markets, sometimes leading to increased aggressiveness. The bond between a population and its resource base, principally water in arid regions, is one of the basic elements that tie demography with international politics. Aggressive behavior and even full-scale wars have often been the concomitants of population stress.

Historically, a correlation can be drawn between conflict and population overgrowth, particularly where demographic strains are put on scarce resources, on their utilization, and on the socioeconomic and cultural relationships between people and their environment, and where migration is not an acceptable option. In the 19th and 20th centuries, the growth of national populations, the quest for resources, and rises in per capita income emerged as important components in the expansionist ambitions of nations, in the nationalist ideological underpinnings of those longings, and, in part, as factors in military expenditures and alliances (Choucri, North 1975; Choucri 1984; Leroy 1976; 1986; Homer-Dixon 1990; 1991b; 1993).[4]

However, population growth is not invariably related directly to conflict or always accompanied by ecological or resource tensions. It is, in fact, hardly ever the solitary cause of conflict. Some issues or situations may be identified as dominant causal factors of strife – and population stress may be one of them – but it is rare that conflict occurs except from a critical mass of interrelated problems that combine in a particular way within circumstances peculiar to a local or regional setting and time. Other options, such as diplomacy, negotiations, and trade can also serve when seeking resources, and emigration or migration (when feasible), can be a means for relieving population pressures, and – most importantly – so too can programs for reducing demographic growth; as will be seen, it has been demonstrated that the benefits of such programs can be experienced in a relatively short time. Emigration is a long-term, limited choice whose effects are normally felt only over decades or generations. In the course of this century, as nations have increasingly restricted or closed down permanent immigration, emigration has ceased to be a viable means for relieving demographic tensions.

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[4] In Choucri (1984), see especially Chapters 1, 4, 6–8. The article by Homer-Dixon (1990) is a longer, earlier version of Homer-Dixon (1993).

There is an exception to the latter proposition: labor migrants who are invited (in some instances lured) to nations where there is a manpower shortage for certain categories of jobs that might range from menial to highly skilled. The relative size of this group is not large in the overall demographic picture, but it is economically and socially important beyond its numbers. For example, the foreign labor force in the Gulf states increased fivefold between 1975 and 1990, rising from 1.1 million to 5.2 million, and by 1990 there were 2.3 million such Turks working in Europe (Omran, Roudi 1993). The receiving host countries look on such migrants as 'guest workers' who fulfill a temporary need and are not usually offered citizenship (unless it is to the highly skilled who might be urgently needed in professions deemed critical to the economy or national interest). There is a 'push–pull' force driving such migrations with both positive and negative consequences. This situation, for example, sometimes offers refugees an opportunity for work, economic improvement, possible citizenship, and other opportunities to better their lives (e.g., Palestinian refugees who serve in countries all over the Middle East, North Africa, and in the West, and Filipino citizens who provide labor to many parts of Asia and the Middle East). The money that such workers send back to their native lands and families not only contributes importantly to the local economy, but often constitutes a significant portion of that country's hard currency reserves. The lot of the migrant workers' families often improves and the government is better able to provide essential services to its citizens.

On the other hand, there is also a 'brain drain' that denies the sending nation the skills and leadership of its most talented citizens – though less developed nations often do not have the economic capacity to absorb all of their professional or, for that matter, their semiskilled and unskilled labor (in the Middle East, Egypt is perhaps the leading exporter of workers). Migrant workers tend to be powerless and are vulnerable to ill-treatment, especially those who do menial work. They are always in the position of an inferior or second class suffering social, educational, and other (sometimes brutal) disabilities even though they may have lived and worked in the host country for more than a generation (as has been the experience of Palestinians in Kuwait). Another serious problem associated with labor migration is that should the receiving nation for any economic or political reason decide it no longer wants or can sustain the migrant workers and sends them home, the impact can be devastating, especially if the action is too precipitous for the home nation to make preparations for the reabsorption of its migrant-worker citizens. The effects of the expulsion of Palestinians from Kuwait to Jordan at the end of the Gulf War were ruinous for Jordan's economy (not to mention the terrible toll on the Palestinians). Jordan has yet to recover fully despite the economic rewards for making peace with Israel.

As a facet of demographically based conflict, environmental and resource-induced large-scale population migrations must be reassessed. The implication of recent studies appears to indicate that there is no clear, convincing link between environmental degradation, large population migrations, and conflict; it is possible that a connection exists, but what linkage can be discerned is remote and indirect. It is clear, especially in the poorer regions of the world, that the combination of environmental degradation, resource scarcity, and migration seems to plunge the migrating group into a swirl of poverty and deprivation. While the precise causes of large-scale migrations may not be altogether clear, it is apparent that they are rarely the outcome of a single factor such as environmental or resource depletion, though the environmental factor may sometimes have a magnifying effect on the causes of migration. Exceptions to this observation are severe, prolonged drought or civil war, but in most cases the migrations engendered by these causes are not necessarily permanent; there is usually a return flow of migrants when the situation improves.

It is also difficult to separate purely environmental from economically inspired migrations, except in extreme situations like flood and drought which produce environmental refugees. The usual causal pattern is a conflation of several related factors with one or two of them being dominant, such as water degradation and scarcity, deforestation, desertification, civil war, terror, etc. Evidence indicates that this has been the case in the Middle East when, over the last two centuries, relatively infrequent large-scale migrations have occurred. Conflict is not the normal consequence of migrations, and environmentally produced migrations are more likely to result in social dislocations and prolonged distress rather than conflict. Migrating populations are almost always destitute, weak, extremely dependent, vulnerable, and lack the wherewithal for starting a conflict or touching off violence. Sometimes migrants are driven to violence by terrible conditions, but generally they tend not to resort to strife unless sufficiently empowered, and when they do, the scale of violence can usually be contained by governments.[5]

WATER AND POPULATION IN THE MIDDLE EAST: CONTEXT

The manifest effects of the world's ascending population size have thus far been tolerable. However, a continued, relatively moderate, acceptable pace of demographically related change of the earth's environment and ecosystems is by no means guaranteed, especially in nations or regions that suffer impoverishment. In the meantime, as population pressures build and resources dwindle in various parts of the planet, barring, at the very least, stabilization if not declension in growth patterns, the prospect is for rising human impoverishment accompanied by suffering, social dislocation, instability, truncated lives, and conflict. Admittedly, these afflictions do not necessarily stem exclusively from demographic causes; rather, they often involve an amalgamation of such factors as climate, political corruption, power struggles and factionalism, ideological extremism, and economic mismanagement – as is the case in several parts of the Middle East and Africa. When these conditions combine with a rate of population growth that is unsustainable in relation to climatic conditions and water resources, the process of disintegration and the consequences are greatly intensified, often making solutions exponentially more difficult to achieve. Somalia in the last decade is an almost perfect model of this process.

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[5] This discussion has been based on Suhrke (1992); for a divergent view, see Choucri (1984).

UN experts have concluded that

> *...at some point in the not too distant future, the [demographically induced] changes may cross a threshold into catastrophe* (Sadik 1990: 10).

In the Middle East, that threshold of catastrophe is discernible on the short horizon. The regionwide population growth rate is about 3.1% per year. If that average rate were maintained, the region's population which doubled in the last 30 years to about 280 million would double again in about 30 years. This in an area where endemically poor soil quality necessitates unaffordable amounts of scarce water for irrigation and huge amounts of chemical fertilizers, which contribute significantly to the degradation of water quality. The prognosis for countries like Jordan, Egypt, and Syria, and for the Palestinians of the Occupied Territories is especially ominous. Their populations are multiplying at annual rates that range from 3 to 3.8%, a growth pattern which is unsustainable in relation to their water supplies. Complicating this picture is an intensification of religiously inspired political opposition to government efforts aimed at curbing population increases.

The Middle East's hydrological problems are abundant. They range from scarcity and maldistribution through mismanagement, pollution, and poverty. Only climate, the ultimate cause of scarcity, surpasses population as the greatest factor of stress on the region's water stocks. In the Middle East, climate mediates the hydrographic relationship between water and population. Judging by the consistently high rate of growth in this century, it would seem that the rise in Middle East's population is almost as difficult for policy makers to control as its climate.

The single, overriding, immutable cause of the Middle East's water scarcity.is the way the earth, in relation to the sun, functions as a stupendous heat pump, generating a constant process of intense evaporation within a broad zone that includes the region (this phenomenon is known as Hadley's Cell). The implications of this situation are multifaceted: the region's fresh water stocks will probably never increase, the margin of safety for sustainable supplies will always be very fragile in most of the area, and on the present trajectory of population growth the region is probably only two or three generations away from disaster – one that may be avoidable if the curve is deflected downward in time.

Our consideration of the reciprocal relationship between population and water in the Middle East requires a few comments on certain characteristics of scarcity. Severe water scarcity or chronic water shortages, when accompanied by such other factors as maladministration, population stress, factionalism, or socioeconomic inequities, can lower a state's capacity to respond effectively to people's needs which results in state weakness and, in turn, produces social disorders which raise tensions and the potential for conflict (again Somalia and Ethiopia come to mind).

However, it must be noted that scarcity is rarely absolute and the principal problems accompanying scarcity are normally those of reduced institutional capacity, management, allocation, and price fluctuations as demands change.[6] Population pressures exacerbate these difficulties and make their solution more complex. In this context, resource use trends become all the more significant for analysts, planners, and policy makers.

Consumptive use trends relative to population growth forecasts are portentous in crucial parts of the Middle East. For example, in the Jordan basin total water use for all purposes presently varies between 2300 and 2500 million cubic meters (mcm) per year among Israel, Jordan, and the Occupied Territories (a little more than 100% of safe-yield stocks). The total population for the three groups is about 13 million. This aggregated population is projected to rise between 2040 and 2050 to 36 million and total water use to 7000 mcm (domestic use – 3620 mcm, industrial – 480 mcm, and irrigation – 2900 mcm).[7]

What these data show, even if they are only within percentages of accuracy, is the magnitude of effort that will be required by all the actors in a little more than a generation to avert a catastrophic situation. It is an axiom of

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[6] On state weakness and resource degradation and scarcity see Goldstone (1991); synoptic versions of Goldstone's views can be found in comments he made at two conferences: the first entitled 'Resource Depletion and the State' at a conference on *The Environment, Resource Depletion, and Conflict*, sponsored by the American Academy of the Arts and Sciences (AAAS), 11–12 May 1992, Washington, DC, the second was at a meeting of the AAAS Project on *Environmental Scarcity, State Capacity, and Civil Violence*, 2 October 1995

[7] See World Bank (1994) and population reviews and estimates, and Arlosoroff (1995, unpublished paper, provided courtesy of the author) in which the same above statistics are quoted.

Middle Eastern affairs that all major events in one part of the region will ultimately have an impact on events in all other areas. Were a prolonged, large-scale demographically-related, water scarcity crisis to overtake the peoples of the Jordan basin, its destabilizing effects would quickly ramify throughout most of the Middle East.

WATER AND POPULATION IN THE MIDDLE EAST: INTERACTIONS

The Middle East lies within the dry areas zone of West Asia and North Africa (WANA) and exemplifies, on a lesser scale, the climatic and arability profile of the WANA region as a whole.[8] The dry areas of WANA consist of 978 million hectares (ha) within the winter rainfall zone, but only 13% of the land is arable, and of that 13%, 35 million ha are under irrigation, while 93 million ha are rainfed; the range of the latter varies significantly from year to year. 75% of the region is desert, some of it at high altitude; the remainder is either naturally flooded or is a wasteland. The climate is generally characterized by winter rainfall and hot dry summers. Rainfall is variable, averaging between a stingy 100–600 mm/year, the highest precipitation falling on coastal areas, with a sharp falloff as one moves inland, away from the coast. Rainfall throughout the WANA region is not only insubstantial, it is erratic within and between years, causing enormous fluctuations in crop production. The length of a crop-growing season, as determined by moisture and temperature, varies between about 70–100 days at high elevations and areas with rainfall of less than 300 mm/year, to 140–210 days in areas with more than 400 mm/year. In the WANA zone, irrigated agriculture is much more important in relation to local economies and production than dryland farming. Finally, the average population growth rate for the entire WANA region is about three percent per year with little sign of abatement.

One of the major consequences of these conditions is that within the WANA region food imports typically constitute over 20% of total imports and represent about five percent of the gross domestic product (GDP). Food imports for the whole WANA bloc account for more than 40% of all food imports by the entire developing world. In fact, the Middle East and North Africa (MENA) is among the largest food deficit regions in the world. By the year 2000, food demand in the region will have climbed to twice what it was in 1980. 60% of that increase will be from population growth and 40% from growth in per capita income. Throughout the Middle East, with very few notable exceptions such as Turkey and Lebanon, the demand for food has already surpassed the carrying capacity of the region's croplands (Lonergan, Brooks 1994: Chapter 2; Gleick 1993: 106; Brown 1996: 12–13).

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[8] This profile is based on TAC Sec't, ICARDA Review (1989: 6–9).

For the Middle East and North Africa (MENA) area, as a whole, the amount of water available per person in 1960 was 3300 m^3; presently, that figure has fallen by 50% to 1250 m^3, the lowest per capita availability in the world (Table 2; Figure 1). By the year 2025, if the region's projected population growth becomes a reality, per capita water availability for the MENA

Table 2. *Worldwide net renewable water distribution by region and per capita*

Continent/region	*Net annual renewable water resources (billion m^3)*	*Population (millions)*	*Per capita (m^3)*
Oceania	7696	21	36619
Latin America	10766	466	23103
North America	5379	287	18742
Eastern Europe and Central Asia (ECA)	7256	495	14659
Africa	4184	559	7485
Western Europe	1985	383	5183
Asia	9985	3041	3283
MENA[a]	355	284	1250

[a] Totals may not adding due to rounding off.

Source World Bank (1996) based on World Bank (1995), WRI (1992), Pacific Institute for Studies in Development, Environment and Security – Stockholm Environment Institute, and World Bank (1995) estimates

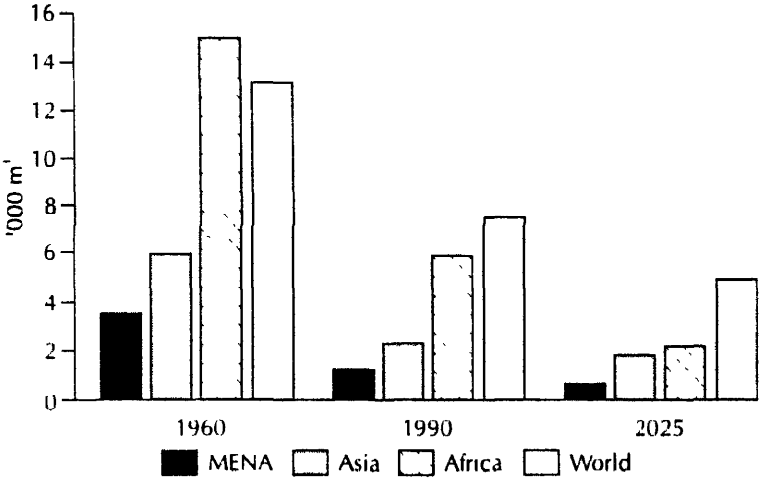

Figure 1. *Projected renewable resources per capita by major region (2025)*
Source World Bank (1996) based on World Bank (1995) and WRI (1992)

region will have fallen by another 50% to 650 m^3. Among the least developed nations of the region, the per capita availability will be as much as four times less than today. One thousand cm/per capita is considered by most experts to be the essential requirement (though that figure is being debated by experts, many of whom argue for a lower one).

Together the Middle East and North Africa are home to five percent of the world's people but contain less than one percent of the world's annual renewable fresh water (World Bank 1996). This circumstance is a fundamental determinant of the region's agricultural outlook. That agriculture is militarily and economically important may be taken as a maxim. Most nations apply that rule by devising policies which will ensure that they are food secure. The nations of the Middle East are no exception, but, for most, given their skimpy water supplies and large populations, such policies are not supportable. Food sufficiency, which is different from food security, is a far more realistic goal in the hydrodemographic context of the region. Food security requires a guarantee of enough food to satisfy a population's minimum nutritional needs over an indefinite period of time, a policy usually expressed as self-contained, domestically produced necessities. Food sufficiency requires that there is ongoing sufficiency of food for the needs and development of a society, attained chiefly by trade from whatever sources. The ultimate reality about food security is that it is absolutely dependent on water security, a condition that climate makes impossible in the Middle East. Thus, attempts to achieve food security will always be a wasteful and ill-fated policy for most nations in the arid Middle East. However, food sufficiency, while a more practical goal, does require an economy that generates enough exports to cover the cost of large food imports.

The Middle East is one of those world areas where there is significant rural to urban migration of the labor force. There is no country in the region that is an exception. Coupled with slow growth in domestic product in most of the area has been the rapid rise in food demand owing to lower real prices, higher incomes, population growth, and large flows of food aid from North America and Europe. Such large-scale food assistance has lowered the real cost of imported food, while at the same time basic food prices have been heavily subsidized in virtually all Middle East countries, thereby encouraging domestic demand and sometimes depressing incentives for local producers.

An integral part of those food subsidies has been heavily subsidized water, for example: almost 100% in Iraq and Syria, 66% in Israel and Jordan, about 75% in Egypt. In several of these countries, the subsidies are off budget; that is, they are not listed as part of the official national expenditures. Overvalued exchange rates and protection for industrial sectors lead to more dependence on foreign imports.

The unadorned fact about water and population in the Middle East is that the limited productivity of the Lower Nile Valley, the Fertile Crescent, and the narrow Mediterranean coastal plain (encompassing the Jordan basin) with their deficient, erratic seasonal rainfalls, and frequent droughts simply will not continue to support the fast-growing population of the region. The average annual growth rate for the Middle East and North Africa, unless significantly reduced within the next 30 years (which appears highly unlikely), will produce sometime between 2015–2020 a conservatively estimated population of between 560 and 610 million people.[9] Of the 30 nations in the world that reached population stability by 1995, none are in the Middle East or North Africa. Moreover, nine countries located in the Middle East (including Jordan and Israel) currently overdraw their renewable ground and surface water supplies. This is indicative of widespread, chronic water scarcity.

There is much about population and resource projections that cannot be reckoned with surety, including whether in the second half of the next century a regional population of as much as 600 million can be sustained by the area's total water and other economic resources even if current patterns of consumption and waste do not persist. What is certain is that with such a projected population, and given the hydrogeology and climate of the region, the water supply and demand ratio will be placed under enormous strain and the more arid and poorer nations of the Middle East will be living constantly on the pointed end of a hydrological crisis (Tables 3 and 4).

CASE STUDY I: THE JORDAN BASIN

Current trends in the Jordan basin offer a very good medium-term illustration of that projection. Consider the implications when the rigid climatic limitations on water supply are added to the burgeoning population of the Jordan basin: Jordan's population and those of the West Bank are increasing at an annual rate of about 3.5% annually – at this rate the doubling time is only about 25 years. The situation in Gaza is especially troubling. In 1992, reports indicated that the growth rate in Gaza reached an incredible 5.8%. In February 1996, the head of the Palestinian Bureau of Statistics stated that Palestinian women in Gaza have an average of 7.44 children and he estimated that Gaza's present population of 934 000 would double in 15 years, adding that

> *Gaza will explode. There will be no job opportunities, insufficient services, a severe housing crisis, and all kinds of other problems* (Jerusalem Post 1996).

Palestinian officials have exhibited reluctance to undertake a rigorous program of birth control because Gaza is the stronghold of Hamas, the radical

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[9] Medium variants were used in all cases; UN (1989: 74–77, 212–213, 226–27, 358–359, 414–415, 422–423, 540–541, 550–551); Sadik (1990: 35–41); CIA (1990), Clarke, Fisher (1972), Naff (1993), Naff, Matson (1984: 12–13)

Table 3. *Population and vital rates (Middle East, 1993–2025)*

Country/territory	*1993*				*2025 population (thousands)*
	Population (thousands)	*Births per 1000*	*Deaths per 1000*	*Natural increase (Percentage per year)*	
Total	264715	37	8	2.9	576426
Bahrain	548	27	3	2.5	1051
Egypt	58292	31	8	2.3	104607
Gaza	694	55	9	5.0	1889
Iran	62847	45	10	3.5	161913
Iraq	19162	45	8	3.7	52615
Israel	5270	21	7	1.5	7994
Jordan	3824	40	4	3.6	8281
Kuwait	1698	32	2	3.0	4574
Lebanon	3552	28	7	2.1	6134
Oman	1644	42	7	3.5	4872
Qatar	499	23	2	2.1	736
Saudi Arabia	17502	39	7	3.2	48749
Syria	13463	45	7	3.8	36529
Turkey	60705	29	7	2.2	98744
United Arab Emirates (UAE)	2096	31	3	2.8	3200
West Bank	1600	46	7	4.0	2980
Yemen	11319	53	21	3.2	31558

Source. Omran, Roudi (1993) based on the 1993 world population data sheet of the Population Reference Bureau

Islamic party which opposes such efforts as being anti-Islamic. The Israelis are increasing at an annual rate of about 1.9% but anticipate an absolute increment of some one million emigrés from the former Soviet Union by the end of the decade. (While the Jewish population in Israel proper is reproducing at 2.6 children per family, close to the replacement level of 2.1, the settlers in the Occupied Territories are increasing above that rate at an average of more than three children per family.)

Using medium, nonlinear projections, and allowing for an anticipated leveling off by the year 2000 to an annual average of about 3.1% and accounting for the relative youth of the population (about 50% is under 25 years of age), by around 2015–2020, Jordan's population would have increased from its present 4.3 million to 7.2 million, Israel's from 5.6 million to 8 million (including the Russian emigres), and the Palestinians in the West Bank and Gaza will jump from 2.75 million to 5 million. At these rates, sometime between

Table 4. *Water availability and usage in MENA countries*

Country	*Annual renewable sources (bcm)*[a]	*Annual withdrawals*			*Water usage (%)*		
		bcm	*As percentage of annual renewable resources*	*Per capita renewable availability in 1995 (cm)*[b]	*Domestic*	*Industry*	*Agriculture*
Algeria	18 40	3 00	16	655	22	4	74
Egypt	58 00	56 30	97	1005	7	5	88
Bahrain	n a	0 20	—	—	60	36	4
Iran	118 30	46 50	39	1826	4	9	87
Iraq	104.00	43 90	42	4952	3	5	92
Israel	2.10	1 90	90	375	16	5	79
Jordan	0 80	1 00	125	213	20	5	75
Kuwait	—	—	—	—	64	32	4
Lebanon	4 80	0 80	17	1200	11	4	85
Libya	0 70	2 80	400	130	15	10	75
Malta	0 03	0 02	67		76	8	16
Morocco	30 00	11 00	37	1083	6	3	91
Oman	2 00	1 30	65	1053	3	3	94
Qatar	0 02	0 15	750		36	26	38
Saudi Arabia	2 20	3 60	164	118	45	8	47
Syria	5 50	3 30	60	385	7	10	83
Tunisia	4 40	3 00	68	489	13	7	80
UAE	0 30	0 40	133	167	11	9	80
Yemen	3 00	3 90	130	176	5	2	93
West Bank and Gaza[c]	0 20	0 20	100	105	12	13	75
Total MENA	355 00	183 00	52	1250	6	7	87

[a] billion cubic meters; [b] cubic meters, [c] allocated between Israel and Gaza (1991), currently under negotiation
Sources World Bank (1996) based on WRI (1992) and Pacific Institute for Studies in Development, Environment and Security – Stockholm Environment Institute, and World Bank estimates, 1990–95

2015–2020 the Jordan basin's population – excluding Syria – will reach about 20 million people. The basin's known water resources will support a population of about 14 million.[10] The resultant questions are manifest – where is the water for the surplus population to come from, and will it be possible to provide it in time to avoid a potentially devastating crisis? Given the complexity of the hydropolitical, economic, and demographic issues involved, in those circumstances 25 or 30 years constitute a relatively short lead time to mitigate the situation.

[10] My own estimate is a sustainable population of about 13–14 million while certain Israeli and Jordanian colleagues estimate 14–15 million. See also Naff (1994).

It may be rationally assumed that where water is concerned, responsible authorities in the Jordan basin will not wait until a crisis is full blown to take steps to mitigate or avoid the problem – although the record of the political leadership in the region is by no means perfect in this regard as attested by the fact that the Jordan basin is already on the cusp of a serious crisis. Nevertheless, let us further assume that a felicitous combination of actions will be taken within the next 25 or 30 years that will ensure the availability of a sufficient supply of water for the projected population – although some hardships may be experienced along the way. That is a possible, perhaps even probable, scenario, though for it to come to pass in any degree, there must first be achieved a sustainable peace agreement between Israel and the Arabs; a peace that would engender sufficient trust to enable the interriparian cooperation essential for an equitable solution to the basin's water problems. Should the current peace-seeking effort be derailed or take an inordinate time, it is conceivable that a major basinwide water shortage crisis could have the salutary effect of forcing cooperation among the otherwise hostile riparians depending on the prevailing political configuration in each country.

However, even with such a peace, it remains dauntingly difficult to avoid the potential crisis posed by the projected population growth rates. Three propositions govern the way in which international water problems may generally be attacked: solutions must be commensurate with the complexity of the problem; the best way to manage issues of apportionment and equitability in international or transboundary waterways is by cooperation among the riparians through some flexible but stable institutional arrangement; and the success of such measures depends vitally on the free flow and exchange of information. Within the context of these axioms, the following are some of the difficult but critical actions that must be considered in any effort to avoid a demographically driven water crisis in the region. All of these steps are ultimately necessary, but the asterisked items are deemed to be essential and must be taken in the right mix, more or less uniformly, and at the right time among all the basin's riparians. To achieve optimal effect, the planning and management of these actions must be coordinated basinwide.

1. There must be a persistent, effective effort to reduce the population growth rate to sustainable levels (only sporadic efforts have been made among the demographically fastest growing countries of the basin).*
2. Information must be shared freely. This requires cooperation in the gathering, standardizing, and processing of information and data.*
3. Substantial reductions must be made in irrigated agriculture (progress has been made in Israel and there will be no further increase in Jordan).*
4. There must be a substantial increase in water recycling and only recycled water should be used for irrigation.*

5. Efficiency in all water-related sectors and branches including management and organization must be significantly improved.*
6. Conservation must be practiced rigorously in all sectors and a heightened public awareness of its necessity must be instilled.*
7. There must be a significant increase in water transport capacity and improvement in distribution efficiency.
8. Large-scale, shared desalination projects must be developed for the entire basin and there must be an assured, affordable supply of energy.
9. There must be a move away from supply-side management policies to demand-side management; this means planning and management must stress risk minimization over maximum utilization.[11]*
10. There must be a reduction of water subsidies and realistic pricing policies.*
11. There must be significant improvements in water infrastructure, including pipelines, irrigation canals, pumping stations, local (metered) delivery systems, etc.
12. Interbasin transfers from such nations as Turkey (together with required pipelines and/or port facilities and pumping stations) must be negotiated.
13. Significant investments must be made in biotechnical research, conservation technology, and new sources of energy, and in the adoption of new technologies.
14. The regional and international financial communities must make available and disburse the necessary (substantial) funds in fair proportion among the basin's riparians in a timely fashion.*
15. The national economic restructuring necessary to accomplish the key parts of these improvements must be undertaken.*
16. There must be effective contingency planning for the probability of prolonged moderate to severe droughts to which the basin is subject.
17. Catchment and storage capacity (including groundwater recharge) must be increased.*
18. There must emerge among the leadership of the various basin governments the sustained vision, will, and courage to face the political and socioeconomic risks involved.*
19. Political stability among the basin's actors must be maintained.*

It is only if the first and last two – always uncertain, always very difficult – items obtain that all of these interrelated, complex actions can be undertaken with hope of success over the next 25 or 30 years. If enough of the key requisites are satisfied, it might be possible for the Jordan basin's water supply to beat the conservative demands of a population of some 17 million or so people. However, attention must be paid to issues of long-run sustainability as well as the exact process through which the reduction of population growth takes place' (Sen 1995: 15–16).

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[11] On this point, see Lonergan, Brooks (1994 27)

The demographics of the situation hold the key to avoiding a major water-driven crisis in the time permitted by current circumstances. Even allowing for water supply increases, if the necessary reforms are undertaken successfully, a continued population rise would soon create a new demand on fixed water stocks already fully utilized and, therefore, incapable of responding adequately.

While the Jordan basin offers us a prime illustration of the hydrodemographic problems of the region, its situation is not unique; with local adjustments, most of the remedies listed for the Jordan riparians – certainly those tagged as essential – would apply to the region's other basins. Along the Euphrates/Tigris basin, the populations of Turkey, Syria, Iran, Iraq, and the nations of the Arabian Peninsula have an average growth of about 3.5% per annum, which means that their numbers will double in the next quarter century (the populations of Turkey and Iran are projected, respectively, to rise to 96 million and 124 million by 2020, and those of Syria and Iraq to 34 million and 45 million). The populations of Egypt, Sudan, and Ethiopia, the Nile river's lower riparians will also experience a doubling of their inhabitants: Egypt's population is expected to rise from 55 million in 1995 to around 98 million in 2020, Sudan's from 28 million to 55 million, and Ethiopia's from 55 million to 129 million.

CASE STUDY II: SYRIA

Within the Euphrates and Tigris basins, the double-barreled problem of water and population is less of supply as it is maldistribution, whose effects can be as pernicious as scarcity. The water sources of the Fertile Crescent can, hypothetically, support a much larger population than at present, but most of that water is controlled by Turkey, the upper riparian on both river basins – 96% of the Euphrates and about 64% of the Tigris. Turkey is in the midst of a vast hydroagricultural project in southeast Anatolia known as the Greater Anatolian Development Project (GAP), which will include a network of some 22 dams, and that could eventually consume the greater supply of both rivers. Should Turkey succeed in fully implementing GAP over the next 25 years (more realistically the next 40 years), and in the absence of an enduring allocation agreement with the two lower riparians, it has been reliably calculated that Syria would receive about 40% less flow of Euphrates water and Iraq's share could be reduced by as much as 70%, possibly even 80% (Kolars, Mitchell 1991). Even if there is an agreement, little doubt exists that Syria and Iraq would still lose flow.

In these circumstances, Syria affords us a model delineation of the systemic connections – and their complexities – of water and population in the Middle East and of the way that the hydropolitical dimensions of water and population quickly branch out into clusters of other riparian issues. Were GAP to be completed in the next quarter century, its reverberations would be felt well beyond the Euphrates through Syria which is a hydropolitical and systemic linchpin connecting the Euphrates, Tigris, Jordan, Yarmouk, and Orontes basins. Syria is a middle riparian on the Euphrates, a middle transboundary riparian on the Tigris, which acts as a border with Turkey for 32 kilometers, the upper riparian on the Yarmouk (a main tributary of the Jordan River), and both a middle and upper riparian on the Orontes – middle in relation to Lebanon where the Orontes rises (and is known as *Nahr al-Assi*, the rebel stream), and upper relative to Turkey through whose territory the Orontes flows for about 50 km. Until 1967, when Israel conquered the Golan Heights, Syria was an upper riparian on the Jordan River. Damascus' relations with Turkey are cool to hostile, with Israel hostile, Jordan cool, and Lebanon controlling. Whatever happens hydrologically and politically in any one or combination of these basins – particularly the Euphrates – will impact on Syria, and, through Syria, on the others.

All of the ramifications for Syria that proceed from a combination of reduced flow from the Euphrates and a population that will have reached 35 million by the time GAP is finished, might not be entirely calculable at this juncture. However, some consequences are foreseeable, beginning with those of the Yarmouk River whose sources rise in Syria and propel the river across the border into Jordan (the total annual average flow of the Yarmouk is only about 425–450 mcm per year). The situation created by GAP (without a satisfactory apportionment agreement) would almost certainly drive Damascus to use significantly more, if not all, of the sources of the Yarmouk. This would reduce the supply to Jordan with serious aftereffects on the latter's economic development plans in which the Yarmouk figures prominently, at a time when the Kingdom's own population will have more than doubled. Syria is already in the process of building a complex of 27 small dams on the tributaries of the Yarmouk.

Israel, too, is concerned about what happens to the flow of the Yarmouk, having withdrawn, yearly, an average of 60–70 mcm of water from that river (and has, at times, taken as much as 100 mcm). This water has been used mainly for replenishing, via Lake Kinneret, its overused coastal plain aquifer, further reducing the availability of Yarmouk water for Jordan. With Israel's own population projected to reach 8 million in 30 years, the importance of this source will increase accordingly, particularly as any final agreement with the Palestinians will require less Israeli water withdrawals from the West Bank. The Palestinians, whose population is expected almost to treble by 2025, understandably insist on taking back most of the water supplies of the Occupied Territories.

Presently, in the negotiations between Syria and Israel, water is an important factor. Although Syria's insistence on the full recovery of the Golan

Heights is motivated chiefly by strategic and political considerations, it is also motivated by the fact that the Golan's Mount Hermon Springs and the Banias River are, together, important sources of the Jordan River. Whoever controls the Heights not only gains the Golan's water supply, but also becomes an upper riparian on the Jordan and is, thus, placed in a position to control part of the river's flow.[12]

At the same time, in the light of GAP, among other considerations, Syria is, and will be, all the more concerned with the maintenance of its influence in Lebanon because, as indicated, the Orontes rises in that country where Israel also maintains a presence. This is another important negotiating salient between Damascus and Tel Aviv that is affected by what happens along the Euphrates. Bear in mind, in this context, that in all of the links of this putative chain of factors, population pressure is an influential moving force.

OTHER COMPLICATING FACTORS

Another complicating and unpredictable variable that must be taken into account in any scenario that is contrived is the impact of militant Islamic revivalist movements that have become ubiquitous in the region. In Islamic law and theology, there are no absolute blanket prohibitions on family planning or the use of contraceptives, which is held to be voluntary; those qualifications that apply to the latter are largely benign. For example, contraception is not permitted when used to avoid female children or to shirk parenthood. Abortion too, is permitted, but not as a family planning method; rather it may be used mainly to preserve the health of the mother. Some Muslim schools of law forbid abortions after the end of the first trimester except when pregnancy imperils the life of the mother (Omran 1992; Omran, Roudi 1993; Musallam 1983). While as yet these militant movements tend to be localized, and no leadership or ideology has emerged under whose banner they can unify across national boundaries, they do already share one demographic notion: they oppose official attempts at birth control as anti-Islamic, western-inspired conspiracies. Should this perception persist and be reinforced by the rise of militant Islamic parties – there is no reason to assume that they will not – the problem of unsustainable population increases in the region will only grow more serious and difficult to manage.

The highly populated nations of the Middle East – some of which face impoverishment – have been, as indicated, obliged for some time to import large quantities of food. Egypt is a prime example: there is a net increase of about one million Egyptians every year, forcing Egypt to become a significant importer of grains, meats, fruits, and vegetables paid for with dwindling hard currency reserves, earned in some measure, paradoxically, by the export of agricultural products. When a nation exports agriculture, it exports water – what can be called 'embedded water'. Given the region's ecological profile – its dry climate, poor soil quality, water scarcity, and unabated population growth – few nations in the Middle East can afford to ship off much of their water in this fashion. Agricultural exports account, on average, for only between three and five percent of gross national product (GNP) across the region. Light industry contributes to GDP 30 times more per unit of water than does irrigated agriculture.

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[12] Discussions between the author and Syrian officials indicate that these considerations are a part of Syria's negotiating strategy.

If ways are not soon found for controlling population growth, and for practicing more rational, coordinated, basinwide water management, the region's water consumers face a certain future of increasingly severe water deficits. It must be stressed that the effects of constant water shortages tend to become magnified because they are cumulative: the deficit becomes progressively larger; aquifers are damaged; water quality is degraded; wells dry up or become useless; crop patterns must be changed; costs rise; and eventually, public health, particularly for the poor, is adversely affected. There is also danger that some of the damage will be irreversible. All of these injurious effects would be very much exacerbated by drought, the occurrence of which, given the region's climatic history, must be taken as inevitable.

ALLEVIATING ACTIONS

However, trends are not destiny. We should not simply assume that a demographic determinism will entirely govern the behavior and well-being of any population; humans have demonstrated ingenuity and creativity when confronted by potentially devastating water crises – almost any great crisis, for that matter. It is probable that the peoples of the Middle East will be able to take steps to avoid – for a time – a general unmitigated disaster. However, unless the population growth rate is stabilized and the trend reversed significantly in the same period, that hard-won success may be short-lived.

It has been reliably estimated that there are some 100 million women in the world who want to avoid pregnancy but have no access to contraceptives. These are the women whose lives are 'most battered' and ground down by too-frequent child birth, particularly in poorer, less developed societies (Sen 1995, 15). This need not be their immutable fate or that of their sisters anywhere. There are, after all, proven, noncoercive, cooperative ways to reverse rapid population growth in relatively short spans of time by uplifting the status of women in the process. It is the broad consensus among demographers that – along with raising per capita income and improving the general economic condition – the most effective means for controlling population growth is by educating women (at least to an eighth grade level, preferably beyond), providing them with opportunities for work outside the home, and giving them access to, and instruction in, the use of contraceptives. When that happens, women acquire greater ability to negotiate the matter of childbearing, use their enhanced economic value to become directly involved in family decision-making, and marry and have children later than their uneducated counterparts.

To realize the full potential of these actions, and to magnify their effects, essential corollary measures must be taken within the male population, including boys, and particularly among those men in the community and family who make decisions in regard to the condition of women. Instructing them with a view to changing their attitudes toward the status of women, inculcating in them the advantages of birth control, and the economic value of educated women not only to themselves and their families, but to the nation as well, must of necessity accompany the process of change for women. This is a process that is, admittedly, bound to be slow, resisted, and painful in many societies – especially those that are deeply traditional – but it is nonetheless of fundamental importance to its success.

Using precisely this approach, Kerala, a socially advanced state in India, was able to reduce its birth rate from 44 per thousand in 1951–61 to 18 by 1991 or, put differently, decrease the rate of fertility to 1.8 children per family, which is below the replacement level – and even lower than China's rate of two children, which was achieved in a little more than 20 years by a combination of draconian measures and incentives (Sen 1995: 15; Yingzhong 1993). These same methods are open to Middle Eastern societies, some of which have already begun to explore them, albeit tentatively.

The unique importance of water for human life can, by itself, lead to conflict or cooperation among the nations of the Middle East. Runaway population growth in conditions of scarcity, maldistribution, and widespread riparian ill-will tilts the balance toward conflict. If the leaders of the region can be made to see themselves as confronting a common fate, to be resolved only through cooperation, and thus, being responsible to and for one another, a positive interaction, very different from the prevailing hostility, may occur. The hydrodemographically based problems of the region are so serious, and there is so little lead time to solve them, that the region's political leaders, whatever their ideological stripes, may be induced by the sheer, overriding necessity of survival, to take cooperative, mitigating actions despite the unavoidable risks and pain. However, the question is, can they, and will they act in time?

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THE 'SECOND INDIA' REVISITED: POPULATION GROWTH, POVERTY, AND ENVIRONMENT OVER TWO DECADES

Robert Repetto[1]

INTRODUCTION

In September 1994, the International Conference on Population and Development debated the consequences of an almost inevitable doubling of world population for human well-being and the environment. New perspectives on gender inequality and reproductive health have come to the fore, but the main issues are still those that were argued at the second World Population Conference in Mexico City in 1984 and at the first World Population Conference in Bucharest in 1974.

Almost 25 years ago, well before the Bucharest Conference, the Ford Foundation in India tried to promote a dispassionate examination of issues that were no less contentious then. It assembled a group of Indian scholars to assess the implications of the doubling of India's population that demographers in 1970 considered inevitable (Ezekial 1975a). Then, as now, India was considered by many to be one of the critical grounds on which the dynamics of population, poverty, and resource scarcity would be played out. Radically different diagnoses and prognoses were being offered. A notable expatriate agricultural expert, impressed with the success of high-yielding rice and wheat varieties, proclaimed

> *Something fundamental and dynamic, with far reaching consequences, has been introduced into the Indian agricultural scene since 1965...the quantum change in technology has been added to a foodgrain production which was already growing at a rate of 2.5% annually since inde-*

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[1] World Resources Institute, 1709 New York Avenue, NW, Washington, DC 20006, USA.

> *pendence. Therefore, it is difficult to imagine a growth rate of foodgrain production over the next decade of less than 3.5% annual trend...We feel that a five percent rate is most probable* (Cummings 1969).

However, equally confident observers predicted disaster – India's inability to eed its growing population. According to Paul Ehrlich's *The Population Bomb*

> *It now seems inevitable that death through starvation will be at least one factor in the coming increase in the death rate* (Ehrlich 1968: 69).

In a widely read book, William and Paul Paddock took an even more ilarmist position.

> *All evidence shows that there is no possibility that sufficient new technology will be developed through research in time to avert widespread famine* (Paddock, Paddock 1967: 78).
>
> *...today's trends show that it will be beyond the resources of the US to keep famine out of India during the 1970s. Indian agriculture is too antiquated. Its present government is too inefficient to inaugurate long-term agricultural development programs. Its population tidal wave is too overwhelming, more than 11 500 000 are added each year to the current half-billion population* (Paddock, Paddock 1967: 217).

Amid these polarized debates, the eight-volume report sponsored by the Ford Foundation, the *Second India Study*, was the most comprehensive and systematic effort up to that time to foresee the consequences of a doubling of population – on demography, urbanization, the economy, agriculture, water, energy, industry, and services. Each author considered events, constraints, and achievements up through 1970 and constructed several plausible scenarios for the future until the year 2000 or beyond. All authors tried as best as they could to link developments across sectors.

Since the doubling of India's population is now in sight, the World Resources Institute (WRI) and another team of eminent Indian experts have compared the scenarios of the *Second India Study* with actual developments. The first objective in reassessing the *Second India Study* was to see to what extent the interplay of demographic, economic, and ecological change could be predicted. Today, optimistic and pessimistic but equally dogmatic pronouncements about the consequences of future population growth are still heard. Is such dogmatism justified? Can even serious scholars accurately foresee what adaptations to current constraints will emerge, or what new problems will materialize? What are the pitfalls of extrapolating current trends into the future?

The answers are mixed. In some areas, India continues to wrestle with many of the same problems today that were obvious in 1970. Managing water, forests, and other natural resources that form India's communal endowment is just as challenging today as it was then. In fact, Indian policy is once again devolving authority and responsibility to local government and community organizations, reversing a decade-long centralizing trend. In urban areas, providing housing, water, sanitation, and other basic services to an expanding city population has proven to be every bit the problem that the *Second India Study* foresaw. So has been the challenge of generating jobs for a labor force doubling in size. In these respects, among others, the *Second India Study*'s vision was accurate.

However, there were external shocks that have fundamentally changed the course of India's economy, which the *Second India Study* could not clearly foresee: the oil price shocks that made India's energy-intensive heavy industrialization pattern irretrievably uneconomic; the accelerating globalization of the international economy, which invalidated India's inward-looking import substitution strategy; the collapse of the Soviet Union and the switch to rapid market-oriented growth in China, which undermined India's commitment to central planning and state-dominated development and has led to the economic reforms initiated in the 1980s, which is still continuing. The *Second India Study* volumes traced out the implications of various assumptions about the future, but one assumption that was not questioned – although it had the most far-reaching consequences – was that India would continue under the centrally planned economic regime that had been established in the 1950s and the 1960s. The gradual liberalization of that regime has been one of the factors enabling the acceleration of India's economic growth in the last decade.

By and large, developments since the *Second India Study* was undertaken 20 years ago fall within the range of scenarios the authors thought plausible. In this sense, the middle ground taken by the *Second India Study* turned out to be the safer position. In general, progress in industrial and agricultural growth, poverty alleviation, and demographic transition has been nearer the pessimistic end of the range of forecasts, although the pace of development quickened significantly during the 1980s. However, there have been plenty of surprises and a few mysteries over two decades of experience. The surprises include those listed below.

- By 1991, fertility rates in the South Indian states of Kerala and Tamil Nadu had reached the replacement level or below, while rates in most of North India still exceeded five over the average woman's lifetime.
- Over India as a whole, natural fertility – the number of births a non-contracepting woman would experience in a lifetime – had risen from about six to about nine, a 50% increase over roughly two decades.

- Despite the continuing shrinkage in agricultural land per person in the countryside, by the late 1980s the percentage of people below the poverty line was lower in rural villages than in cities.
- Throughout most of the period, there were shortages of coal and coal-based electricity, though domestic reserves of coal are ample. By contrast, reserves and production of petroleum and natural gas, which were thought to be scarce, have greatly increased.

The *Second India Study* anticipated some problems that have not materialized. The authors greatly overestimated the resource requirements of India's economic development. They discounted the impact of new technologies that would be adopted, even in India's relatively closed economy. For example, virtually the entire steel industry converted from open hearth to electric arc furnaces, greatly reducing energy requirements. The cement industry shifted from wet to dry processes with similar results. Also, the emphasis on the heavy industry, characteristic of India's development strategy in the 1960s, was moderated. As a result, much less steel was needed for machine building, railway construction, and the like. Fewer railway lines and cars were needed to carry coal and less coal was needed to feed steam boilers and industrial furnaces. Even though India's economic policies during the period provided few incentives to conserve resources, structural and technological change nonetheless worked to that end. As a result, the environmental impacts and capital requirements of India's growth – large as they turned out to be – were substantially less than they would have been under *Second India Study* scenarios.

It is also true that problems that were not foreseen have materialized. In agriculture, for example, despite the optimism generated in the 1960s by the success of high-yielding wheat and rice seed varieties, an extensive agricultural research effort in India has been unable to demonstrate continuing yield improvements for major crops over the 1970s and the 1980s. Newly released seeds and agronomic input packages tested on farmers' fields have failed to show upward yield trends in the past two decades (see Figure 1). Whether this represents deterioration in underlying soil fertility, weaknesses in the agricultural research effort, or genetic limitations in the plant materials available for use is unclear. Whatever the cause, average farm yields continue to rise, but toward a static ceiling of demonstrated research results.

Overall, the record of the *Second India Study* teaches both the value of serious efforts to look ahead at the implications of massive population expansion and the need for a certain humility in making predictions. The Study did identify many of the key challenges that India would face and raised some of the key policy issues that policy makers needed to confront – and, by and large, have confronted – over the succeeding two decades.

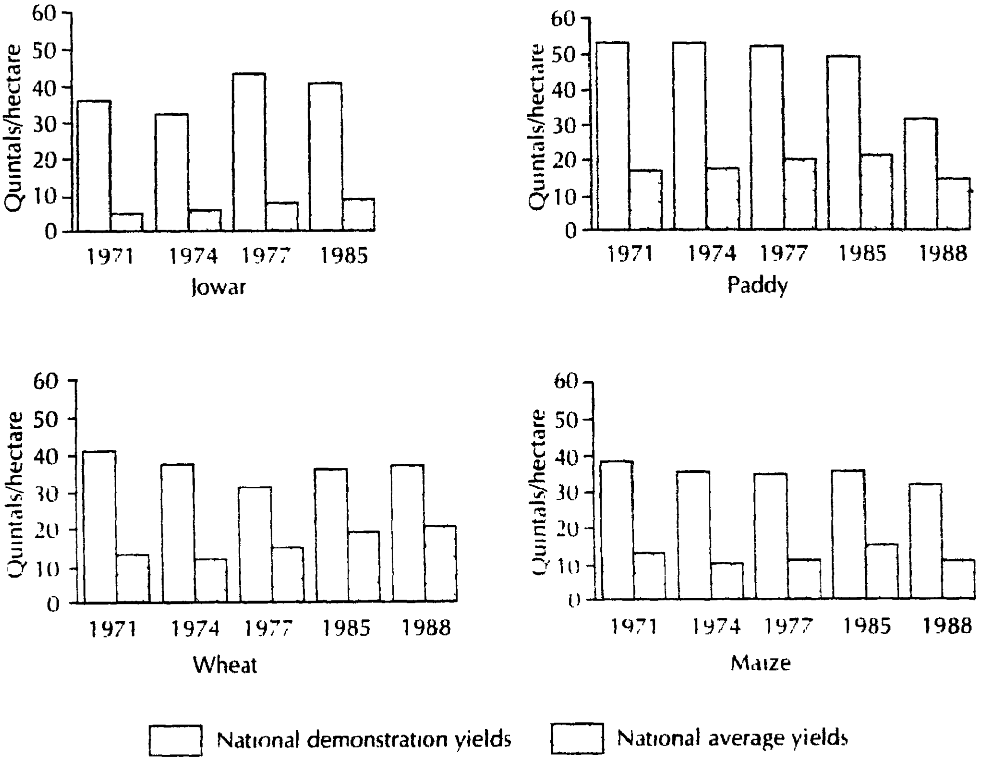

Figure 1. *Yields from major grain crops*
Source. Vaidyanathan (1993: Table 5).

THE MAIN TRENDS AND INTERACTIONS

Another objective in reexamining India's experience, using the *Second India Study* as a benchmark, was to trace out the key interactions of population growth, economic development, and environmental stress over 20 years. The conclusions of the *Second India Study*, though varied, were basically optimistic that poverty and population growth could be reduced despite India's limited financial and natural resources. However, the authors emphasized that doing so depended not so much on the availability of technology as on solving difficult and long-standing social and institutional problems.

These judgments were basically correct. The disasters predicted by Malthusian pessimists have not happened and India has continued to develop economically over the past two decades. However, progress has been toward the low end of the *Second India Study* projections, certainly much slower than hoped in the Government of India's various five year development plans and slower than that observed in many other large developing countries in Asia.

The population growth rate between 1970 and 1990 was only very slightly lower than it had been during the previous two decades: 2.1% per year compared to 2.2% (see Figure 2). The 1991 census counted 846 million Indians, almost as many as in the highest *Second India Study* projection of 849 million and 32 million people more than the lowest. By mid-1994, the Indian population had increased further, to about 900 million. The population increase since 1971, when it stood at 548 million, has been larger than the total increase in the six earlier decades of the 20th century (Srinivasan 1993: 1). In

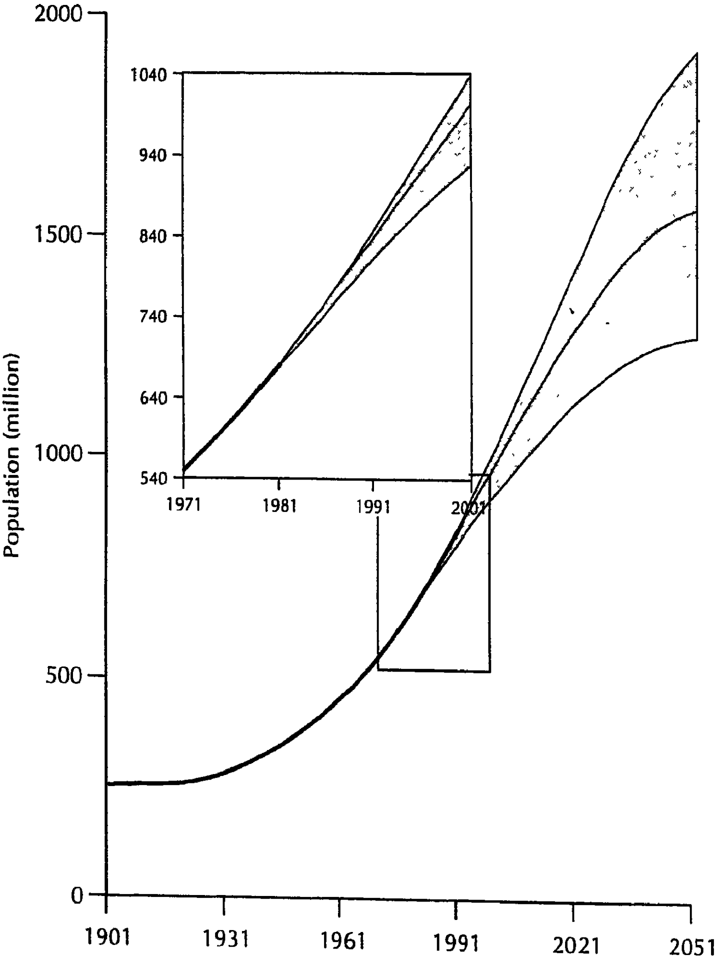

Figure 2. *Population growth*

Note. Shaded area represents range of projections; the bold line is actual growth.

Sources. Ambannavar (1975); 1991 census data from GOI (1991) as reported in Bowonder (1993).

fact, if the people added to India's population since 1971 inhabited a country of their own, it would be the world's third most populous country, smaller than only China and India itself.

Near constancy in the growth rate masked the underlying demographic transition: crude birth rates and death rates did fall substantially, but in parallel. About 80% of the overall fertility decline is the consequence of the more widespread use of birth control devices by married women. The percentage of couples using contraceptives rose from 10 to 40% over the period, largely through the efforts of the government-supported family planning program. Per thousand of population, health personnel and clinical facilities expanded by 50% or more.

A key linkage with socioeconomic development has been the rise of natural fertility, which has historically been only about six live births per lifetime among Indian women. Despite the tradition of early and universal marriage, religious and cultural restrictions on sex, prohibitions against widows remarrying, prolonged breast-feeding, malnutrition, and the effects of malaria, tuberculosis, and other diseases contributed to low natural fertility. As many of these cultural practices have weakened, and as life expectancy and general health conditions have improved, natural fertility has risen substantially, to approximately seven in the 1970s and eight to nine by 1991. Thus, India's decline in birth rates has occurred against a substantial rise in natural fertility, a consequence of economic development (Srinivasan 1993: 19–21).

What has emerged most strongly, over the past 20 years since the *Second India Study*, is the importance of social and cultural determinants in the demographic transition – especially the place of women in society (Basu 1993: 2–6). This is demonstrated dramatically in the variations from state to state within India in both birth and death rates and in their close association with indicators of women's status – such as female literacy (see Figure 3). Fertility has fallen across India, in villages as well as in cities, and regional differences have become more pronounced. In a socioeconomically backward northern Indian state such as Uttar Pradesh, where traditional attitudes persist and a woman's status is low, the total fertility rate declined only from 5.9 to 5.1 between 1984 and 1991. In South India, fertility, which by 1984 had already dropped to 2.4 in Kerala and 3.3 in neighboring Tamil Nadu, fell further to 1.8 and 2.2, respectively – replacement level or below.

Life expectancy at birth in India in 1990 had reached 60 years a substantial increase, consistent with the *Second India Study* forecast. Although infant mortality rates have fallen, poverty-related diseases stemming from high fertility, maternal malnutrition, and exposure to respiratory and gastrointestinal infections still predominate. Maternal mortality rates in India are still about 50 times higher than in high-income countries. In rural areas, only about one-third of deliveries are attended by trained personnel in equipped facilities – although this ranges from 77% in Kerala to only 1.5% in Rajasthan (UNICEF 1991: 12–17).

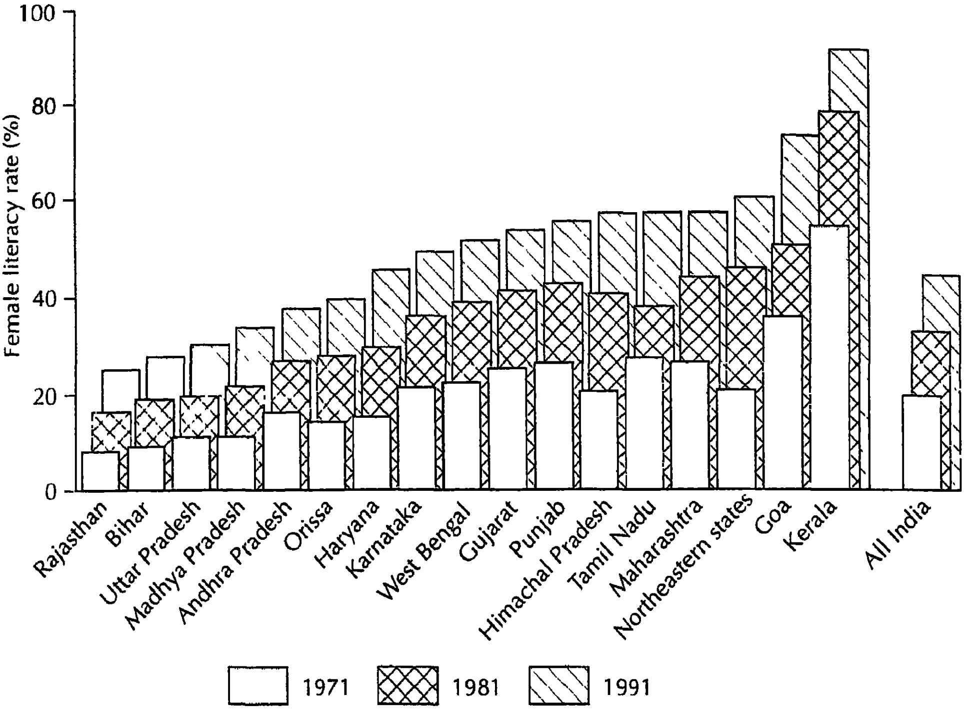

Figure 3. *Female literacy by state*
Sources. GOI (1971; 1991).

Deaths of children under five accounted for nearly half of all deaths in 1971, but less than two-fifths by 1986 and close to one-third by 1991 (World Bank 1993: Table A6). Although the majority of children still experience moderate or mild malnutrition, including debilitating vitamin, iron, or iodine deficiencies, the percentage of children suffering from severe malnutrition fell by half from the mid-70s to the late 1980s, in part because of governmental food distribution and child feeding programs (Bowonder 1993: 20).

However, in the North Indian Hindi-speaking states of Rajasthan, Haryana, Uttar Pradesh, and Madhya Pradesh, survival chances are considerably worse for girls than boys once infancy is passed. Little boys are given priority in feeding and medical expenditure; little girls must often make do with what's left over. In contrast to most other countries, India's population contains increasingly fewer females than males: 927 per thousand males in 1991, compared to 930 in 1971. In the large North Indian states where women are sequestered and discriminated against, including Bihar and Punjab as well as those mentioned above, this sex imbalance is pronounced. Women's survival chances are lower and they may simply not be counted at census time (Basu 1993: 21; Srinivasan 1993: 6). Health surveys consistently find that when women fall ill, they typically wait much longer before seeking medical help, if they do at all.

India's experience since the *Second India Study* demonstrates that both services and development are important in demographic transition. India's expanding network of primary health centers and family planning clinics, its food distribution and nutrition interventions, its immunization and communicable disease control programs, and its investments in schooling and safe water supplies have helped lower mortality rates beneath those typical of countries at comparable income levels. However, poverty, illiteracy, malnutrition, and unhealthy living conditions elevate death rates in many parts of India. Similarly, although the Government of India has sustained a massive family planning program, which has contributed to the fertility decline, the slow pace of economic development during the 1970s retarded the pace of demographic change. The growing differences in birth rates among India's regions demonstrate the importance of modernization and social equity.

As the *Second India Study* had foreseen, between 1971 and 1991 the labor force increased to 123 million, growing faster than the total population. In the 1980s alone, it increased from some 290 to 350 million, which is 22% higher than the *Second India Study* projection. The employment problem turned out to be even more intractable than the *Second India Study* had anticipated.

The working age population (15 to 59) increased from 52 to 55% between 1971 and 1991, but the overall labor participation rate remained virtually unchanged at 41–42% of the total population, implying that the percentage of working age people actually working has decreased. A larger proportion of young people are continuing their education. Moreover, even though female participation rates are rising in rural and urban areas, they are so much lower in urban areas that urbanization has reduced female labor force participation rates overall. Participation rates are 54 and 50%, respectively, for rural and urban males, and 34 and 14% for rural and urban females. In much of India, it remains more acceptable for females to work on their household farms or in family activities than outside the home.

Contrary to conventional theories about population economics, India was able to raise its household savings rate significantly despite continuing rapid population growth. But, low real returns on investment muted the impact on growth. Between 1970/71 and 1990/91, gross domestic product (GDP) growth in constant prices averaged four percent, toward the low end of *Second India Study* forecasts and no better than the average in the rest of the developed or developing world. There was, however, a substantial step up from three percent in the 1970s to 5.3% in the 1980s (see Figure 4).

The dominant economic model of the 1960s presumed that in successful development experiences, unproductive workers in agriculture would gradually be absorbed by rapid growth in other sectors. As growth was slow until the

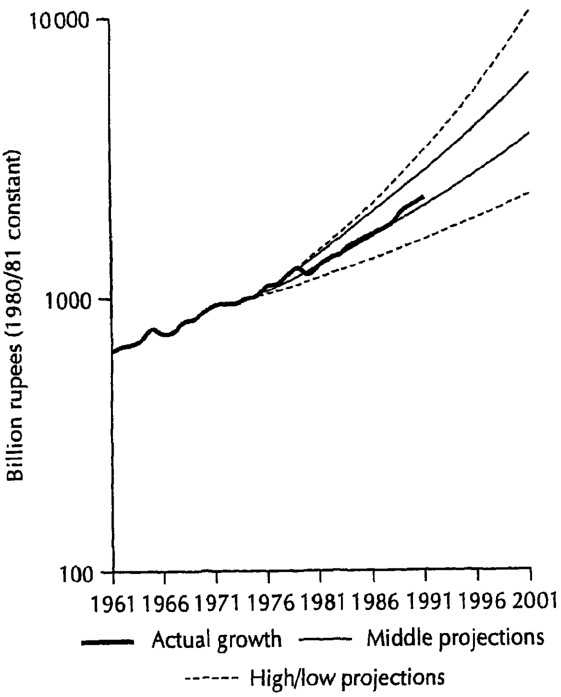

Figure 4. *GDP* Second India Study *projections* versus *actual growth*
Sources. Mehta (1976); GOI (1993a).

1980s and the capital–labor ratio rose throughout the organized sectors of the economy and agriculture, formal employment opportunities failed to increase sufficiently to absorb new labor force entrants and cut into the enormous residue of underemployment. The economy seemed to be playing out the worst case scenario depicted by the *Second India Study*. Agriculture's share of the labor force fell only slightly, from 70% in 1970 to 65% in 1987/88, and the average value added per worker in agriculture fell from only 27% of that in the rest of the economy to less than one-quarter – one reason why rural poverty persisted.

Agricultural production continued to rise at virtually the same trend growth rate observed in the 1950s and 1960s, even though the net cultivated area has not increased in the past two decades. The Green Revolution did not fail, but neither has it produced a quantum increase in the growth of foodgrains output. Foodgrains production per capita has increased by only 5.4% despite 20 years of agricultural development efforts. Supplies have been adequate to meet market demand and to improve the diet of the average person somewhat, but overall calorie availability from all foods rose very modestly. According to available survey data, which are far from conclusive, the percentage of households with adequate protein and calorie intake increased between 1975 and 1989 in some states (including Gujarat, Madhya Pradesh and Orissa) but, on an average, fell slightly in the eight large states surveyed (Bowonder 1993: Tables 13–14; see Figure 5). Among children under five, an especially vulnerable group, the percentage suffering from severe or moderate undernutrition fell from 72 to 60%, according to survey data (UNICEF 1991: Table 2.16). This improvement in a still unsatisfactory situation probably stemmed from lower birth rates, increased access to postnatal care, child health services, and nutritional interventions through several public health and food distribution programs, and, especially, advances in the educational status of young mothers. Nutritional deficiencies in young children often stem from repeated bouts of diarrhea and respiratory infections, which impair their ability to absorb food even when they eat enough. Hence, improvements in children's health care – especially by their mothers – is critical (UNICEF 1991: 29–30).

The Green Revolution really took hold in the alluvial river basins where tubewell irrigation during winter months was possible It allowed production to continue expanding by increasing yields, mainly on irrigated or well-watered lands, even after the limits of cultivable acreage had been approached. Dryland agriculture has lagged further behind, so regional dispari-

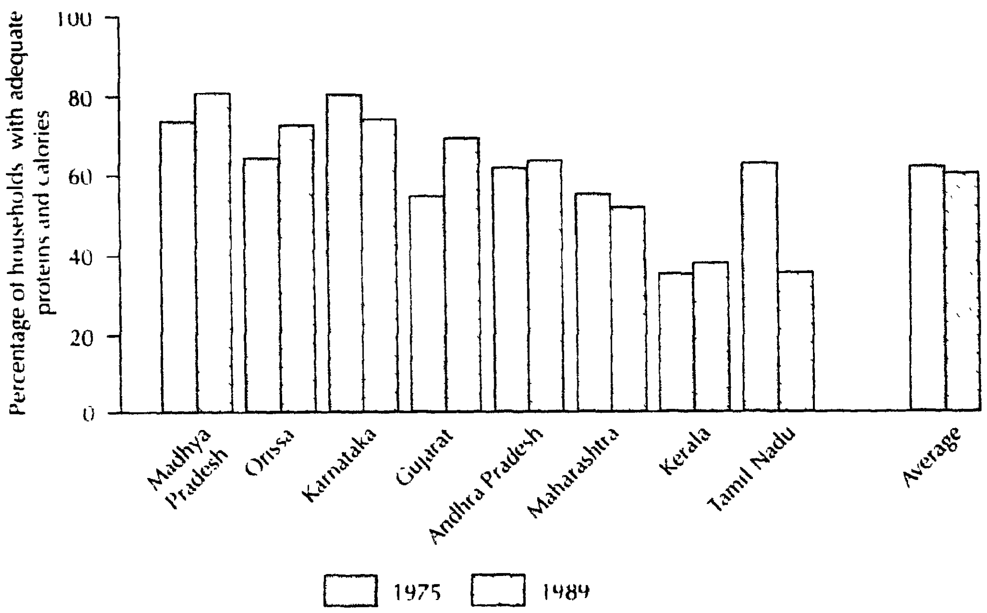

Figure 5. *Calorie and protein intake adequacy in selected states*
Source. GOI statistics (National Nutrition Monitoring Bureau) taken from UNICEF (1991).

ties in rural incomes have increased. Population growth supposedly acts as a spur to agricultural intensification. However, interregional differences in the growth of agricultural production had little to do with differences in population densities or population growth rates, and much to do with differentials in the pace of tubewell irrigation development (Vaidyanathan 1993: 24).

The total area under crops in India has remained nearly constant for the past 20 years. Any new lands brought under the plough just offset areas converted to other uses or lost to soil degradation. For example, about 8.5 million hectares, six percent of the cropland base, went out of production because of waterlogging, salinity, or excessive alkalinity. Gullying and erosion took other large areas. The modest seven percent increase in the gross area cultivated stemmed entirely from increased double-cropping on irrigated farms (Vaidyanathan 1993: 23, Table 9). As the rural population grew, average farm size fell from 2.3 to 1.7 hectares between 1971 and 1986. By the late 1980s, over three-quarters of all holdings were less than two hectares in size, and almost three-fifths less than one hectare – too small to provide full-time livelihood or subsistence to an average sized family. At the same time, the number and total area in large holdings – over 20 hectares – also diminished (Bowonder 1993: 21–23). Total landlessness in rural areas increased only slightly, and the concentration of agricultural land changed a little.

In the Green Revolution areas, rising incomes have generated employment opportunities but pumpsets, tractors, and chemicals have replaced labor in farm operations, limiting the growth of farm employment. In lagging agricultural areas, where water is unavailable or poorly controlled, shrinking land–man ratios have exacerbated existing labor surpluses. A growing percentage of the rural labor force has had recourse to casual wage employment off the farm, some of it generated by governmental rural employment and other targeted antipoverty schemes. After the national election of 1972, development policy shifted dramatically to attack poverty and underemployment directly through publicly funded employment creation, food distribution, and antipoverty programs, rather than relying on overall economic development.

By far the most encouraging labor market indicator is the improvement in real wages virtually throughout India since the GDP growth rate started to pick up (Hanson 1990; Krishnan 1991). Even in the 1970s, agricultural real wage rates for males rose in all but four states (Punjab, Haryana, Maharashtra, and Assam). Between 1980 and 1987, they rose in all major states and quite rapidly in some. Per day worked in Orissa, a man could support 1.9 persons at the poverty level for a day in 1970 and 2.5 people by 1987. In Madhya Pradesh, another poor state, these numbers were 1.8 and 3.2 respectively, and in a better-off state such as Gujarat, 2.8 and 4.5.

Real agricultural wage rates for females moved upward even more consistently. In the 1970s, they declined only in Bihar, and in the 1980s only in Tamil Nadu. The median increase from the early 1970s to the mid 1980s was

2.7 and 1.8% per year for females and males, respectively. In 12 out of 15 states, the ratio between female and male wage rates improved, and the median ratio went up from 0.71 to 0.82. This change probably reflected the increased need for small farmers to seek off-farm employment and the consequent tendency for their spouses to take over the farm work.

This evident rise in real wage rates, signalling some tightening of labor markets, is reflected in the data on poverty trends. The most commonly used poverty indicator is simply the percentage of the population below the 'poverty line'. This measure omits a household's asset and debt position, its access to public and communal resources, and even the extent to which its expenditures fall short of the poverty line. The availability of publicly financed services and of communal resources greatly affects the living standards of low income households. Fuels, fodder, and a variety of foods and materials gathered from the wild have traditionally met as much as one-fourth of the total consumption needs in low income households. All over India, such communal resources have become scarcer, but in some regions the situation is far more acute than in others. Since consumption and expenditure surveys do not capture the diminished availability of such gathered resources perfectly, they understate the vulnerability of the rural poor and overstate any improvement in welfare.

An expert group instituted by the Planning Commission recently reviewed earlier poverty estimates and produced a revised set that the government has adopted. They show steady overall progress in reducing the prevalence of poverty in India, from 55% of the population in 1973 to 45% a decade later, and to 39% in 1987/88, the latest year for which National Sample Survey data are available (see Figure 6). However, because of the population increase during these years, the number of people below the poverty line fell by less than five percent, from 322 to 313 million between 1973 and 1988.

Rural and urban poverty trends converged over this period because the rural poverty rate fell almost twice as fast – from 56 to 46% between 1973 and 1983 and then to 39% by 1988. In urban areas, where the poverty rate also declined from 49% in 1973 to 42% in 1983, it was still at 40% in 1988. By the late 1980s, not only had poverty become more prevalent in urban areas, the number of poor people in cities had increased by 23 million, an increase of almost 40%.

It is ironic that the *Second India Study* authors were gravely concerned about the urban bias in India's development patterns, which had created enormous disparities in living standards between city dwellers and villagers and which they saw as the source of an irresistible pull toward the cities. Their demographic prediction has been validated; over the past 20 years the urban population has doubled, increasing at twice the rate of the rural population (Mathur 1993: 6). Even the largest metropolitan areas, Bombay, Delhi, and Calcutta, have doubled in population. Although India's urbanization has not been particularly rapid by developing country standards, 100 million people

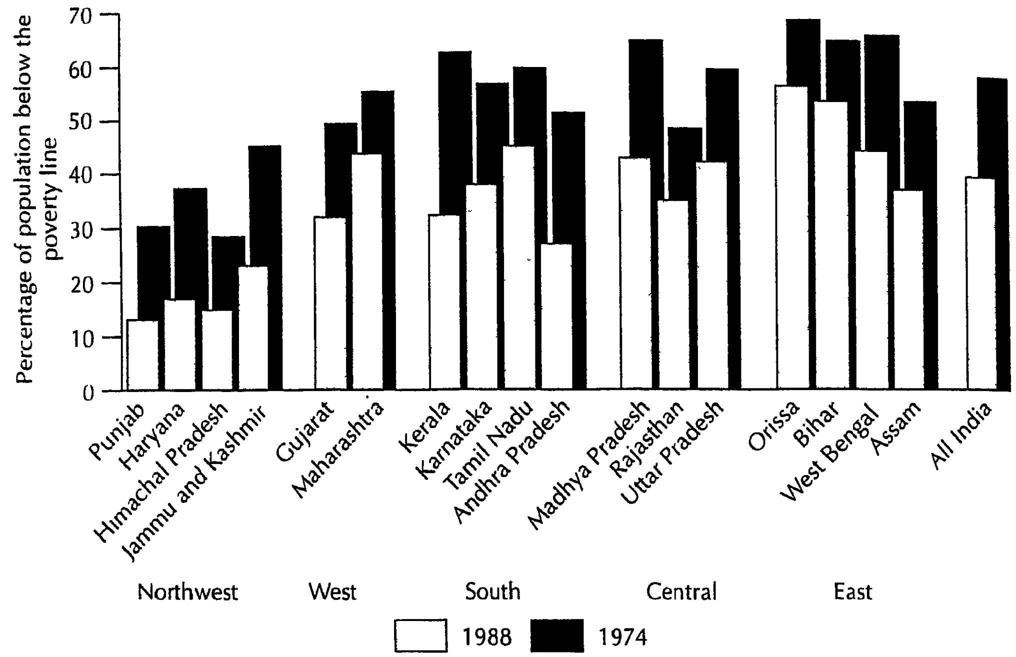

Figure 6. *Poverty prevalence by state*
Source. GOI (1993b).

have been added to the urban scene, and, the disparity between per capita production in rural and urban areas has widened. However, urban poverty has emerged as a growing, unanticipated problem.

Urban poverty increased partly because of rapid urban growth in poverty stricken states. Moreover, within the cities, poorer and less educated households tended to be those with the highest birth rates. Slow economic development, and, in particular, slow growth of industrial output and employment, failed to provide the engine that could pull these rapidly increasing urban populations out of poverty. Industrial growth provides not only direct factory employment, but also the ancillary opportunities in transportation, trade, construction, and other services that provide jobs for the urban poor. In urban areas, employment in large and medium-sized industries has also grown much more slowly than output, which itself has increased more slowly than in other developing Asian economies. Capital–labor and capital–output ratios rose in most Indian industries over the period. The fact that industry grew slowly and also became increasingly capital-intensive over most of this 20-year period closed opportunities to most of the urban poor.

For these unfortunates, the quality of the environment can be a matter of life or death. The gap between the need for essential urban services and their availability has widened. Population densities in cities increased by 20%

between 1971 and 1991, forcing increases in urban land values and making it increasingly difficult for low income households to find space. In the 23 largest cities, 28% of the people now live in squatter settlements, twice the percentage for all of India (Bowonder 1993: 28). Housing in these settlements is typically makeshift, constructed from scrap material – sometimes just rags and straw. Only one household in 20 in these *bustee* settlements enjoys a *pucca* house of permanent construction. Most of the squatter settlements are established on undesirable land – subject to flooding, near heavily polluted industrial sites, or other hazards. Moreover, very few have sewers, drains, or facilities for collecting and disposing of garbage and other solid wastes – ideal conditions for the spread of communicable diseases.

On the other hand, in some of the largest cities, such as Calcutta, the quality of life is better now than when the *Second India Study* was written. In particular, progress has also been made in providing access to safe water in Indian cities. According to official statistics, almost 90% of the urban population now has access to protected drinking water, compared to 78% in 1981, although for the urban poor the source is typically a public tap and supplies may not be sufficient (Mathur 1993: Table 21). Yet, rivers and streams bordering urban settlements, still widely used for bathing and washing, are heavily polluted by human and industrial wastes, as are shallow aquifers underlying cities from which many households draw well water. In coastal cities that have overdrawn their groundwater supplies, such as Madras, the intrusion of salt water into the aquifers has created serious water supply problems. Heavy pollutant loadings and increasing urban population growth have compounded the problems of providing adequate water supplies.

Less progress has been made in the collection and treatment of human wastes, which can be inordinately expensive if conventional sewer systems and sewage treatment plants are used. Over half the urban population, 125 million people, have no access to basic sanitary facilities, but must make use of 'open spaces' surrounding slum settlements (from the National Institute for Urban Affairs, cited in Mathur 1993: Table 25). This fosters the spread of fecal-borne diseases, such as dysentery, hepatitis, helminthic infections, and cholera. According to 1988 data, in cities with populations of 100 000 or more, only 22% of the sewage generated was collected, and, of that, only 62% received primary and secondary treatment. Of the 241 towns with fewer than 100 000 inhabitants, which contain one-third of the urban population, only 19 have wastewater collection systems, and only 10 have treatment facilities (from the Central Pollution Control Board, cited in Bowonder 1993: Tables 6–8).

The urban poor are exposed to other environmental hazards. Most still rely on fuelwood and biomass fuels, which they must purchase at rising prices in the marketplace. Women cooking with these fuels in tiny huts, using makeshift inefficient stoves, are exposed to incredible concentrations of smoke, as are their children; the consequences include high levels of bronchitis and respiratory infections – often fatal in malnourished young children – and chronic eye irritation and infections. As many squatter settlements are clustered in industrial areas, along roadways, and in other congested urban areas, these urban poor are highly exposed to air pollution from vehicles and industries. In the 20 years since the *Second India Study*, the number of vehicles on the road in India has increased 10-fold and city traffic jams are commonplace. Two-thirds of the vehicles on the road, almost all in urban areas, are two-wheel motor rickshaws and scooters powered by high emissions two-stroke engines. Poorly maintained buses and trucks spew forth highly toxic diesel emissions. Gasoline in India still contains lead, and lead concentrations found in samples taken from India's children are extremely high. Exposure to lead impairs the mental development of children.

These environmental hazards are particularly dangerous to the urban poor because they compound the problems of malnutrition, general ill-health, and the lack of medical care. The well-known interplay of diarrhea, weight loss, malnutrition, and vulnerability to respiratory infection is a deadly cycle to which many Indian children succumb. To this must be added the risks of exposure to high concentrations of air pollutants, known to have more serious harmful effects on those whose respiratory functions are already impaired. As a result, infant mortality rates in urban slums in 1989 were 123 per thousand, compared to the all-India rate of 98, the overall urban rate of 62, and an infant mortality rate of 22 among urban households above the poverty line (Srinivasan 1993: Table 7; Mathur 1993: Table 26).

This overwhelming burden of sickness cannot but lower the productivity and earnings of adults, who must work every day for a living, and perpetuates poverty in these unhealthy environments. Women, in particular those who suffer from inferior access to health care and even to food, but who nonetheless must work long hours, are soon debilitated. Children, who also suffer chronic sickness, malnutrition, and vitamin deficiencies, cannot attend school and learn effectively if they are sick and hungry. Hence, their hopes of escaping the trap of poverty are also undermined.

In most respects, India's rural environment has deteriorated markedly since the *Second India Study* was written. In canal-irrigated areas, dams are rapidly silting up because of deforestation upstream, and millions of hectares of farmland have become waterlogged or salinized because water has been applied improperly. In large areas where tubewell development has been intensive, water tables are falling; in coastal areas, salt water is invading and ruining the aquifers, depriving tens of millions of people of drinking and irrigation water.

Much of India's farmland has long been deficient in nutrients and organic matter. Organic matter is rapidly oxidized in the heat, leached, or eroded away during monsoon rains, or removed through repeated cropping and burning of plant and animal residues. Yet, because of the rural energy deficit, the quantity of organic manures applied in India declined by 20 to 25% between 1975 and 1991. The runoff of eroded topsoil into India's rivers and estuaries, estimated at around 25 billion tons per year, contains nutrients equivalent to all the chemical fertilizers used in the country. Even though chemical fertilizer use is growing rapidly, micronutrient deficiencies have emerged as important constraints on plant growth in much of India; large percentages of soil samples are deficient in such elements as zinc, iron, and copper (Bowonder 1993: 6). Thus, the additional crop output obtained from increases in chemical fertilizer use declined substantially over the period, even though farmers have become more familiar with chemical fertilizers and improved seed varieties, and despite the spread of irrigation.

Pesticide use rose by six percent annually over the period. Nearly 70% of the pesticides used in India, including DDT, aldrin, methyl parathion, and benzene hexachloride (BHC), are banned or severely restricted for agricultural uses on health grounds in some other countries [Center for Science and the Environment (1985), cited in Joshi, Singh 1991: 97] There are no comprehensive systems for monitoring exposure levels or comprehensive data on health impacts, but local surveys give clear warning signs In the Punjab, the leading agricultural state, pesticide contamination of food was pervasive in the 1970s, especially in milk and dairy products. 73% of the milk samples from Ludhiana district had excessive DDT residues, averaging five times the legally permitted level. Even mothers' milk contained DDT and BHC residues several times higher than permitted levels. In a Punjabi cotton-growing district, DDT intake through mother's milk was 24 times the acceptable daily intake. Use of these compounds continues to increase. Recent findings implicating these estrogen-mimicking compounds to reproductive disorders are grounds for substantial concern (Colburn, Clement 1992). More powerful and toxic organophosphates such as methyl parathion have also come into use. Although these substances break down faster and do not accumulate in tissues as DDT does, their use involves both acute and chronic health risks. In a more recent study in an urban market in Rajasthan, 40% of the vegetable samples were contaminated with organophosphates [Gupta (1990), cited in Joshi, Singh (1991)]. Since these pesticides may impair the human immune response, they are potentially dangerous to malnourished children subject to repeated infections, since the immune systems of such children are already stressed. This syndrome illustrates the complex linkages among poverty, demographic factors, and the environment.

In the uncultivated parts of rural India, two-thirds of the total area, overharvesting of fuelwood and overgrazing of livestock, combined with unsustainable rates of commercial exploitation, have devegetated the landscape. Neither central nor state government authorities have been able to ration access to these communal resources effectively and equitably. Large-scale soil erosion and disruption of hydrological flows have resulted. Increasing shortages of fuelwood, fodder, and other useful products of India's commons have added to the deprivations of the rural poor, especially women, who are most dependent on those resources (see Figure 7). Most of India's varied native ecosystems now exist only in remnant patches, under great pressure from surrounding populations and commercial interests. Shrinking habitats have reduced the numbers and the ranges of India's magnificent and diverse plant, animal, and bird populations, endangering many.

VICIOUS AND VIRTUOUS CIRCLES

Participants in the original *Second India Study* saw the diverging paths in India's future, some leading toward development and prosperity but others leading to deeper poverty and degradation. They emphasized that steps in ei-

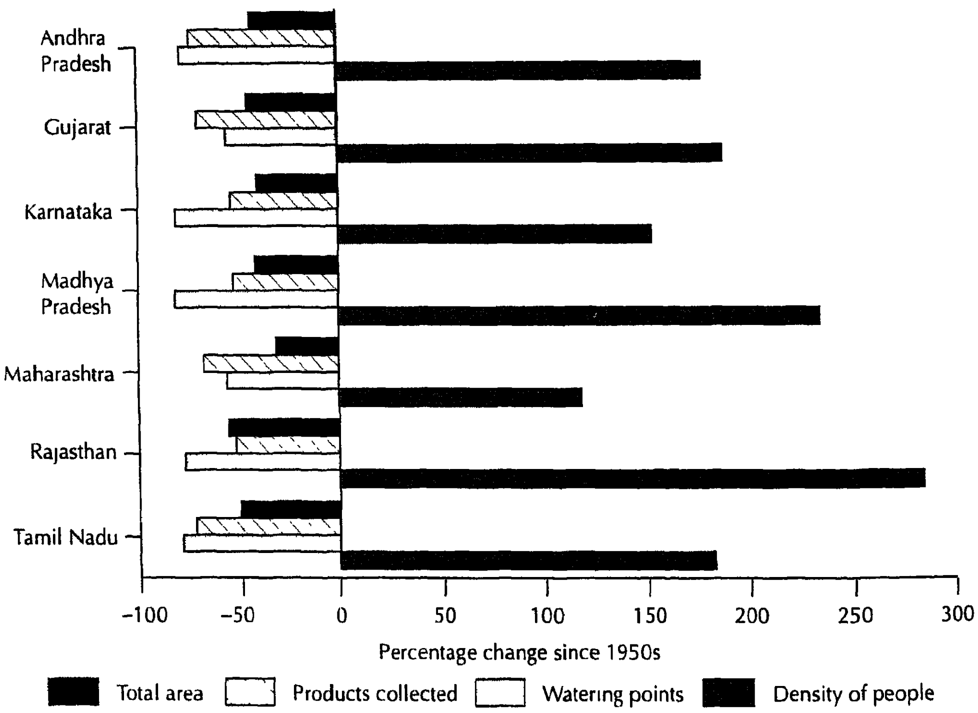

Figure 7. *Decline of common property areas*

Note. Products collected include fruits, flowers, leaves, roots, timber, fuel, etc. Watering points include grazing common property resources only.

Source Joddha (1992: Table 6).

ther direction would be self-reinforcing, propelling the nation down one path or the other. As Hannan Ezekiel, the author of the overview volume, put it

> *I was deeply impressed by two things. One was the existence of vicious or virtuous circles of interaction having profound implications for the likely state of the economy at the end of the period. The other was the critical role of policy in determining whether these relationships would, in fact, operate to produce vicious or virtuous circles...*(Ezekiel 1975b)

The overall interplay between population, poverty, and resource availability was described in such terms. Here is his description of the dark scenario

> *Income will grow slowly. Population will grow rapidly. Per capita income will, therefore, grow very slowly. This will have a negative impact on family planning efforts...Also, savings ratios will not rise and may even fall...Industrial growth will be slow. Growth in industrial employment will be even slower...The existing land hunger will increase. Further subdivision and fragmentation of land will take place. Propagation of new techniques of cultivation will become more difficult...In this context, talk of social justice will be mere nonsense. The proportion of the population below the poverty line will certainly increase...The employment situation will also worsen and it may well be that the ability of the socioeconomic system to cover it up in various forms...will prove to be inadequate...Communal, caste, regional, or economic groups will fight with one another with increasing bitterness in order to obtain for themselves a share of the limited real resources, income, and employment available in the country* (Ezekiel 1975b: 189–190).

While this dark vision finds some reflection in events in India since the early 1970s, the striking trend is the increasing differentiation of development patterns. While some regions stagnate, others move briskly ahead. In fact, both virtuous and vicious circles are evident in India's diverse regions. In Kerala, for example, women have long enjoyed better status and opportunity. Women obtained more education and married later. They gained greater access to professional and other socially sanctioned employment, which cemented their position and authority within the household. For all these reasons, contraceptive use and fertility decline took hold early in Kerala. This, in turn, allowed women to pursue education and careers more easily, and increased their social status and economic opportunity. Today, 85% of Kerala's women are literate, the infant mortality rate is comparable to that in New York City, and fertility is below replacement level.

By contrast, in northern and northwestern states, such as Rajasthan, women typically married outside their own villages and were secluded within their husbands' household, virtually excluded from paid employment except in extreme circumstances. Status came from mothering sons. Girls received little education, married early, and commenced childbearing. With little autonomy or education, most women's opportunities outside the home were virtually nil. Thus, their social status remained low, and few girls received more than rudimentary education. Marriage age stayed low, and high birth rates continued. In Rajasthan today, only 20% of the women are literate, only 30% of the married couples practice contraception, and the average married woman has five to six children.

Other vicious and virtuous circles affect India's environment and resources. The British colonial government assumed authority over almost all of India's forests and uncultivated regions, all but abrogating the traditional rights and regimes of village communities, tribal societies, and other groups that had used these resources – more or less sustainably – for generations. After independence, succeeding central and state governments were largely unable to restrain access to this vast domain in the face of rising populations and demands for raw materials. When demands surpassed sustainable yields, a cycle of depletion and degradation was set in motion. Seeing others taking the increasingly scarce resources without stint, none saw reason to restrain their own demands. Thus, overexploited stocks and harvests shrank, as population and demands on what remained intensified. As the value of communal resources deteriorated, village leaders increasingly withdrew from attempts to manage what remained, leaving the rural poor to glean what they could from the ever-shrinking woodlands and pastures.

In a few areas, the cycle has been interrupted and reversed. Communities assured of the equitable and exclusive use of the commons have limited overexploitation and cooperated in rehabilitation programs. Investments in restoration have raised productivity, diminishing the pressure to overexploit the resource. Higher returns have provided the resources for further investments, leading to further increases in productivity. Although only in exceptional instances has the notorious tragedy of the commons thus been reversed, these promising examples have led to a needed reexamination of development policies.

THE PRIMACY OF INSTITUTIONS AND POLICIES

The authors of the *Second India Study* made clear their views that India had the power to choose options that would generate employment, reduce poverty, accelerate the demographic transition, and avert resource crises. They emphasized that neither the technology available at that time nor the availability of natural resources precluded India from raising living standards for a doubled population. The agricultural technologies needed to double yields and production on both dry and irrigated farmland existed then. India also possessed enough energy resources to meet the needs of cities, industries, and villages.

According to the *Second India Study*, by choosing policies that spurred rapid employment growth, the government could deal effectively with poverty and malnutrition within the economic system, rather than by attempting to mitigate the failures of economic development through special antipoverty interventions. By reducing poverty and investing heavily in education and health, the government could ensure the success of the family planning program and accelerate the demographic transition. Further, the promotion of community woodlots, biogas plants, and rural electrification by the government could provide enough fuel and forage to relieve pressure on India's common property resources. By better managing water resources and by integrating surface and groundwater systems, India could expand its irrigated area without environmental damage. The question was whether India would choose these successful options

Looking back at the past 20 years confirms the correctness of this point of view. Neither technologies nor resources have been the intractable problems. Rather, where development has faltered, the stumbling blocks have usually been institutional and policy related. The key issue has often turned out to be that of creating mechanisms, whether through market incentives, community organizations, or other means of governance, for bringing the interests of the individual into line with those of the broader community. Where this has happened, the circles have been virtuous; where it has not, the circles have been vicious and the dynamics destructive and unsustainable.

In family planning, the government has continued to emphasize the technologies of birth control, first the intrauterine devices, then male and female sterilization. An extensive service network has been constructed to provide these technologies throughout India, with substantial impact on those ready to terminate childbearing. However, what has become increasingly evident is the importance of social institutions that afford women social status, autonomy, and opportunity – not only to regulate their fertility but to satisfy their health, and economic and social needs as well. In parts of India, where women can fulfill these needs, their own interests in family planning coincide with those of the larger community.

In other realms, similar findings emerge. For example, persistent energy shortages have, indeed, robbed India of badly needed output and employment, depriving the urban and rural poor alike. However, neither technology nor natural resources have been constraints. India has large coal reserves and far more oil and gas than was suspected 25 years ago. One reason for scarcities of commercial fuels has been the failure to price energy high enough to ration demand and generate funds for reinvestment. Another reason has been continued reliance on inefficient public sector monopolies. In rural areas, renewable energy technologies and potential biomass resources have been available, but too few resources have been allocated to meet the energy needs of the rural poor, and too few community governance structures have been built and supported to reverse the notorious tragedy of the commons.

In agriculture, India has successfully promoted the use of its underground water resources and the new green revolution technology to meet its food requirements. Where farmers could invest in electric or diesel powered tubewells, and control their own water supplies, the use of modern agricultural technologies has paid off, and farmers have rapidly increased their yields and incomes. Local water markets have emerged through which those without wells could share in the benefits. By contrast, in large canal irrigation systems, where the interests of farmers come into conflict, politicized irrigation administrations have been unable to allocate water efficiently and equitably. Compared to tubewells, canal irrigation still remains typically unreliable or inadequate and has increased agricultural yields much less.

Moreover, because groundwater exploitation was heavily subsidized on a first-come, first-served basis, the better-off farmers were allowed control of an immensely valuable resource at virtually no cost, and an opportunity was missed to allocate more rural assets and income to small farmers and agricultural workers. Where water scarcities emerged, the absence of any effective means to limit the individual farmer's withdrawals has led to depletion or ecological damage. By concentrating its fiscal resources heavily on the alluvial areas where tubewells were advantageous, the government put the lagging dryland and flood-prone regions at a disadvantage, allowing rural income disparities to widen.

The evidence that has emerged in India over the 20 years since the *Second India Study* was carried out suggests that rapid demographic transition, poverty alleviation, and development can occur simultaneously even in poor and populous countries. However, unsustainable spirals of population growth, environmental degradation, and impoverishment are also possible. Population growth such as India's makes it harder to reduce underemployment and poverty, raise educational levels and environmental quality, or provide adequate infrastructure and basic services, but it does not make these tasks impossible. The key determinants of success seem to lie in the social framework, broadly conceived to include the system of norms, economic arrangements, policies, and institutions of governance.

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POPULATION, DEVELOPMENT, AND ENVIRONMENTAL CONDITIONS AT THE VILLAGE LEVEL DURING 1981–1991: AN EMPIRICAL STUDY USING CENSUS DATA IN KOTA DISTRICT OF RAJASTHAN STATE, INDIA

K Srinivasan, Sanjay Kumar[1]

INTRODUCTION

The district of Kota is located in the south-eastern part of the state of Rajasthan in India (Figure 1). It is medium-sized, with an enumerated population of 2.03 million as per the 1991 census. In 1992, following the census, the district was bifurcated into two – Kota and Baran – with minor boundary adjustments from the neighbouring districts. The population of the bifurcated district stands at 1.22 million. This article attempts to study the village-level demographic, developmental, and environmental conditions of undivided Kota.

To facilitate comparison, a basic demographic profile of Kota and Rajasthan is given in Table 1. In 1991, 36.4% of the population in Kota was residing in urban areas, as compared to 22.9% of the population in the state as a whole. The literacy rate stood at 64% and 29.5% for males and females, aged seven and above, respectively. For the state, these figures are 55 and 20.4%. Over the decade 1981–1991, the district recorded a growth rate of 32.3% compared to 28.4% for the state in the same period. The relative 'index of development' of the district, as computed by the Centre for Monitoring of Indian Economy (CMIE 1995), based on a number of developmental parameters was 119, compared to 69 for the state. These parameters indicate that Kota is one of the most urbanized, industrialized, and economically advanced districts, adjudged from the macro level condition of the state. The newly formed district of Kota is even more urban and industrialized than the

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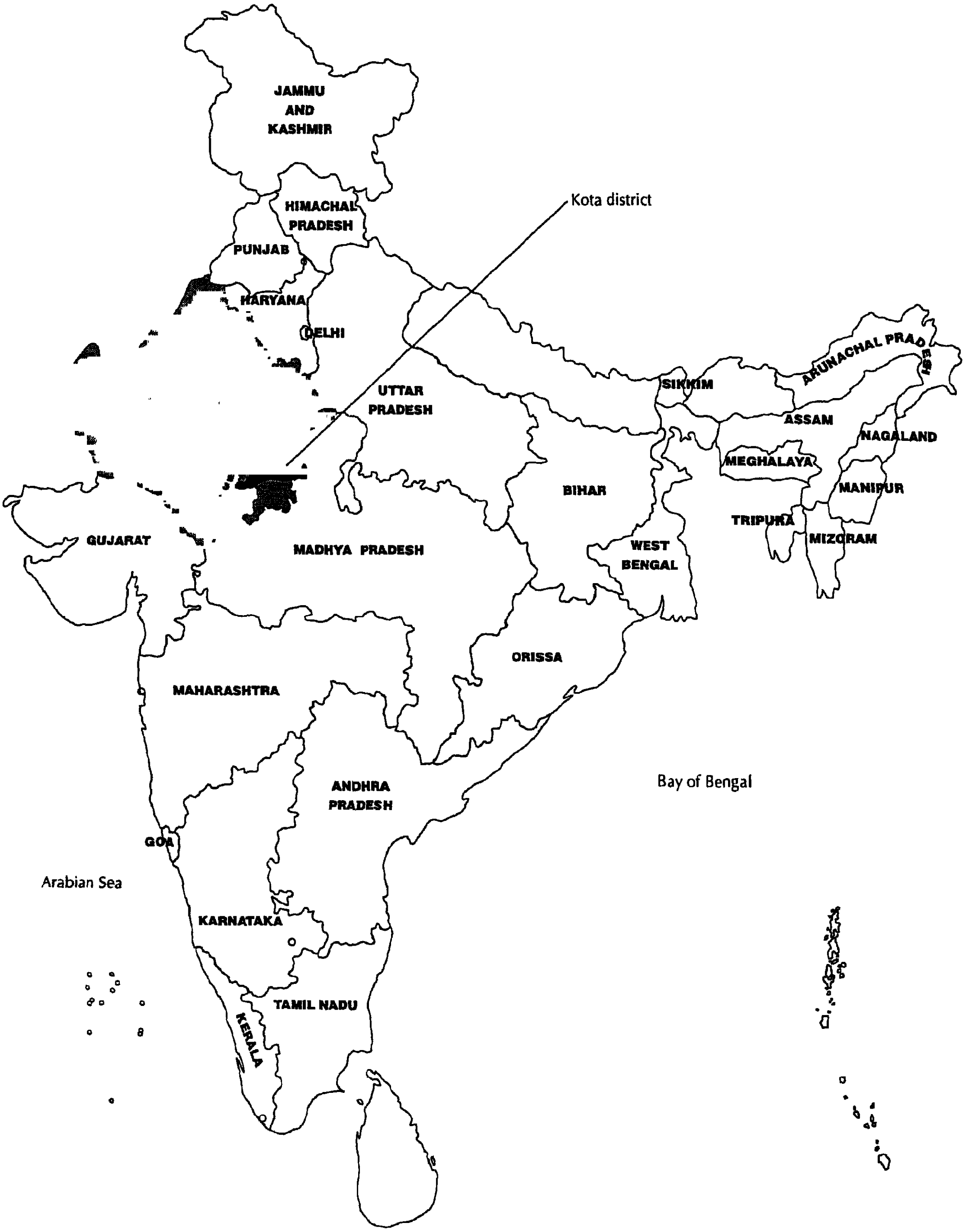

Figure 1. *The location of Kota in Rajasthan, India*

Table 1. *A comparative profile of Kota district and Rajasthan* (1991)

Profile	*Kota*	*Rajasthan*
Land area (km²)	12436.00	342230.00
Population		
Total	2030831.00	44005990.00
Males (m)	1076184.00	23042780.00
Females (f)	954647.00	20963210.00
Rural	1290996.00	33938877.00
Urban	739835.00	10067113.00
Exponential growth rate (annum; %)	2.63	2.50
Decadal growth rate	+32.32	+28.44
Density of population (per km²)	163.00	129.00
Percentage of district to total population of state	4.61	—
Percentage of urban population	36.43	22.88
Percentage of scheduled castes	19.72	17.29
Percentage of scheduled tribes	14.20	12.44
Sex ratio (f/m)	887.00	910.00
Percentage of main workers to total population	31.41	31.62
Number of villages	2101.00	39810.00
Number of inhabited villages	1881.00	37889.00
Number of towns	12.00	222.00
Relative index of development[a]	119.00	69.00
Literacy rates (%)		
Total	47.88	38.55
Males	64.03	54.99
Females	29.50	20.44

[a] From CMIE (1995)

undivided Kota district. Kota symbolizes the nature of changes likely to occur in the other districts of the state of Rajasthan and, possibly, in other states with the accelerating pace of industrialization set in motion in the country during the past five years.

It would be interesting to study the nature of changes that have occurred in the villages of Kota district, particularly from the point of view of developmental and environmental conditions at the village level. The lessons that could possibly be drawn from such an analysis would help in devising rural and urban developmental strategies.

The nature of industrialization in the district of Kota is primarily in the form of stone-cutting and polishing activities,[2] coloring and twisting of synthetic fibre yarns, and manufacturing auxilliary parts for automobile industries. None of these activities require educated workers. Illiterate men and women can obtain gainful employment in such industries by learning these skills either on the job, or by practising them at home. For example, crude granites are delivered at home for cutting and polishing, and the wages are paid on receiving the cut and polished stones. This has generated a substantial increase in employment in the nonagricultural sector in the district. This includes the rural populace as well as traditionally employed in the agricultural sector.

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[2] Kota district is famous for its black granite stones.

The nature of employment is such that one need not find any strong positive association between literacy levels and employment in the nonagricultural sector at the village level, as is often assumed in economic analysis, at least in the early stages of development. Similarly, without an increase in the educational levels of the population, especially that of females, and the availability of urban facilities of cooking gas and electricity in the households, it is possible that the traditional practice of using wood for heating and cooking purposes would continue despite the fact that the people are engaged in nonagricultural activities.

Furthermore, with the increase in the population size in rural areas, on account of high fertility levels, there is a possibility of a decline in the common property land holdings in the villages (or the 'culturable waste') in proportion to the land area. This could be attributed to the need to bring larger areas under cultivation in order to feed the growing populations. The 'culturable waste' is a part of the common property of a village community and is used by the rural poor, especially those without any land of their own, for grazing their cattle and raising fodder or fruit trees. Such 'culturable waste' can be regarded as a buffer for the very poor in rural areas. With the growth in the wealth of agricultural land owners, consequent to the Green Revolution, and as a result of bringing larger and larger cultivable areas of the village under irrigation, there is an increasing demand for cultivating land under 'culturable wastes' and converting it into private property. In many other cases, it can also be used for construction of houses to meet the needs of the growing population (Jodha 1989; Ranjan 1996). A reduction in the 'culturable waste' could be regarded as an indicator of environmental stress on the society. Such stress can be caused by the demographic and developmental factors of the population. Similarly, in areas with declared forests, the proportion of forest lands to the total land area may decline because of the use of such forests for the collection of firewood for cooking and heating purposes. A reduction in the density of forests is possible without any change in the declared forest area. However, such a change is hard to measure from any secondary data sources. Thus, we can postulate four hypotheses.

1. Development, both economic and social, will be influenced by the population size of the village because of the possibilities of location of schools and other infrastructural facilities in large-sized villages.

2. At the village level, there would be significant positive association between the proportion of labour force employed in the nonagricultural sector and literacy levels among males and females, though such a relationship may not be strong.
3. At the village level, there will be a significant negative association between the common property land or the 'culturable waste' and economic and social development. This may be unrelated to the population size.
4. The proportion of forest land to the total land area of the villages will be negatively and significantly correlated with social and economic development and population pressures.

DATA SOURCES

The Census of India, conducted in 1981 and 1991, has published village-level information on a few parameters that permit analysis of the current situation and decadal changes on selected demographic, developmental, and environmental conditions of the district. This information was a part of the Primary Census Abstract. Among the variables on which data were available, information on the following was compiled for the villages of Kota district for 1981 and 1991 for the testing of the above hypotheses (Registrar General, India 1983; 1994).

1. Population size at the village level in 1981 and 1991 (POPT81, POPT91).
2. Percentage of the labour force (main workers) employed in the nonagricultural sector.
   - In total population (NAGT81, NAGT91)
   - In male population (NAGM81, NAGM91)
   - In female population (NAGF81, NAGF91)
3. Percentage of total land area of the village brought under irrigation (IRR81, IRR91).
4. Percentage of the total land area of the village in culturable waste (CUW81, CUW91).
5. Percentage of the land area under forest (FOR81, FOR91).
6. Percentage of literate population.
   - Among total (PLIT81, PLIT91)
   - Among men (MLIT81, MLIT91)
   - Among women (FLIT81, FLIT91)

For 1991, the literacy rate is based on population aged seven and above, while for 1981 it is based on the total population. Hence, the comparison of the literacy rate between 1981 and 1991 has to be carried out with caution.

To test the above hypothesis, an analysis of the relationships among the above variables was carried out using correlations and multivariate analysis.

ANALYSIS AND FINDINGS

Data were available on all the above 10 variables for 1367 villages of Kota district for 1981 and for 1593 villages for 1991. For 1225 villages, data were available on all the variables for both the census years, facilitating comparison.

Table 2 presents the mean values of the selected variables of the villages classified by their population size. The variables included are population den-

Table 2. *Mean value of the selected variables across different population size categories of villages: Kota (1981; 1991)*

Variable	*Population size class of the villages*					
	All villages	*< 250 (very small)*	*250–499 (small)*	*500–749 (average)*	*750–999 (large)*	*1000 and above (very large)*
POPDEN (per km^2)						
1981	120.00	67.00	107.00	123.00	142.00	194.00
1991	150.00	66.00	123.00	150.00	158.00	221.00
CUW						
1981	11.28	12.27	11.72	10.25	11.02	10.83
1991	10.22	10.86	10.29	9.83	9.57	10.55
IRR						
1981	16.47	9.95	14.29	19.58	18.89	22.77
1991	24.43	15.71	20.07	25.16	28.51	31.01
NAGM						
1981	15.59	11.56	12.67	14.58	15.42	27.20
1991	13.88	9.70	9.92	11.94	11.69	23.73
NAGF						
1981	18.47	12.81	18.33	21.39	14.18	24.46
1991	11.83	7.77	9.20	14.83	8.47	16.32
NAGT						
1981	15.25	11.26	12.93	14.55	14.01	25.93
1991	12.79	9.05	9.11	11.22	10.49	21.76
FLIT						
1981	5.51	3.50	4.38	5.38	5.66	10.04
1991	10.94	6.68	8.51	10.52	11.72	15.91
MLIT						
1981	32.17	32.26	30.11	35.66	37.02	41.36
1991	47.91	31.88	42.17	50.14	53.86	57.53
PLIT						
1981	19.49	12.91	17.86	21.23	22.09	26.45
1991	30.48	20.03	26.33	31.49	33.94	37.88
Number of villages						
1981	1225	243	386	259	130	207
1991	1225	159	332	266	175	293

sity per square km (POPDEN), culturable waste as a percentage of the total land area of the village (CUW), percentage of the irrigated land to the total land area of the village (IRR), percentage of the main workers engaged in nonagricultural activities (NAGM for males, NAGF for females, and NAGT for the total population, respectively), percentage of the population found literate (FLIT for females, MLIT for males, and PLIT for the total population for 1991 based on those aged seven and above, and for the entire population for 1981). The villages have been grouped into five categories on the basis of population size: 'very small' (less than 250 persons), 'small' (250 to 499 persons), 'average' (500 to 749), 'large' (750 to 999), and 'very large' (1000 and above). The 'small' and 'very small' villages have significantly declined, both in terms of number and the total population they support. The number of very small villages declined from 243 to 159 and their share of the rural population declined from 20.1 to 13.1% during the decade 1981–91. The social and economic conditions of villages classified as 'small' or 'very small' are significantly lower than the 'average', 'large', and 'very large' villages. This is true for 1981 and 1991 for the economic and social conditions as well. For example, the means of the percentages of village land under irrigation in 'very small' and 'small' villages were 9.95 and 14.29 compared to 18.89 and 22.77 for the 'large' and 'very large' villages in 1981. In 1991, the means were 15.71 and 20.07 in 'small' villages compared to 28.51 and 31.01 for the 'large' villages. The percentage of the females literate in 1991 were 6.68 and 8.51 in the 'very small' and 'small' villages compared to 11.72 and 15.91 in 'large' and 'very large' villages. The data clearly reveals that the level and pace of development of the villages is considerably influenced by their population size. This can be explained from the fact that the location of schools, roads, markets, and other infrastructural facilities are likely to be associated with the size of the village. Smaller villages are grossly lagging behind others in all aspects of development. Special developmental strategies need to be adopted for such villages (Hypothesis 1).

Table 3 presents data on the mean values of selected indicators of villages classified by the level of 'culturable waste': 'very low' (less than 4%), 'low' (4 to 7.9%), 'average' (8 to 11.9%), 'high' (12 to 15.9%), and 'very high' (16% and over). The table reveals that the villages with a higher proportion of 'culturable waste' have generally lower levels of development in terms of female literacy, proportion of area under irrigation, and the percentage of male workers employed in the nonagricultural sector. For example, the mean value of the percentage of males employed in the nonagricultural sector decreases across higher 'culturable waste' land villages from 14.80 to 11.84 with an exception for the category of villages under average 'culturable waste'.

Table 4 presents data on the mean values of selected indicators for villages classified according to the proportion of females literate in the population aged seven and above in 1991. The table reveals that the proportion of 'culturable waste' in the village seems to be negatively related to the literacy

Table 3. *Mean value of the selected variables across different categories of culturable waste villages: Kota (1981, 1991)*

Variables	Percentage of culturable waste to total area of the village					
	All villages	< 4% (very low)	4–7.9% (low)	8–11.9% (average)	12–15.9% (high)	16% and above (very high)
POPDEN (per km²)						
1981	121.00	126.00	104.00	114.00	131.00	137.00
1991	150.00	156.00	130.00	146.00	172.00	168.00
IRR						
1981	16.47	21.74	17.32	16.32	15.41	11.60
1991	24.43	30.97	24.46	25.54	21.01	15.43
NAGM						
1981	15.59	18.98	15.50	16.58	15.80	11.52
1991	13.88	14.80	13.79	15.07	13.40	11.84
NAGF						
1981	18.47	24.87	19.95	17.74	17.65	10.08
1991	11.83	11.51	11.25	12.17	10.73	13.65
NAGT						
1981	15.25	19.19	15.22	16.22	15.50	10.62
1991	12.79	13.70	12.83	13.68	11.81	11.17
FLIT						
1981[a]	5.51	5.84	6.12	6.24	5.53	3.57
1991	10.94	10.78	12.36	12.26	9.47	8.02
MLIT						
1981[a]	32.17	30.75	34.91	34.20	32.82	27.05
1991	47.91	45.61	51.73	51.67	46.76	40.41
PLIT						
1981[a]	19.49	18.95	21.25	20.81	19.80	15.95
1991	30.48	29.19	33.13	33.13	29.05	25.28
Number of villages						
1981	1225	214	362	269	172	244
1991	1225	262	369	244	142	208

[a] Based on the whole population

level of the village. For example, the percentage of 'culturable waste' in villages with 'high' female literacy (20% and above) was 8.24% compared to 11.62% in 'very low' literacy villages (less than five percent). In other words, as there is social development, the environmental stress on the village seems to increase with a decline in the common property resources or the 'culturable waste'. On the other hand, an increase in female literacy in the village is accompanied by economic development, indicated by the increasing

Table 4. *Mean value of the selected variables across different categories of female literacy villages, Kota: 1991*

Variables	*Female literacy*					
	All villages	*< 5% (very low)*	*5–9.9% (low)*	*10–14.9% (average)*	*15–19.9% (high)*	*20% and above (very high)*
POPDEN (1991)	150.00	122.00	152.00	160.00	176.00	181.00
CUW (1991)	10.22	11.62	10.81	9.61	8.60	8.24
IRR (1991)	24.43	15.22	25.01	28.80	35.53	31.93
NAGM (1991)	13.88	9.60	12.17	15.32	15.53	22.29
NAGF (1991)	11.83	10.81	12.87	12.69	7.43	14.69
NAGT (1991)	12.79	9.21	11.26	13.93	13.72	20.24
MLIT (1991)	47.91	29.09	48.93	56.75	61.58	68.98
PLIT (1991)	30.48	16.35	29.26	35.82	40.52	49.85
Number of villages (1991)	1225	441	243	193	132	215

proportion of irrigated land to the total area of the village. In the 'very high' female literacy villages (20% and above), 31.93% of the land was under irrigation while only 15.22% of the land was under irrigation in the 'very low' literacy villages (less than five percent). Similarly, the proportion employed in the nonagricultural sector in the villages is very strongly and positively associated with the level of female literacy in the village. Thus, at the village level, social and economic development seem to go hand in hand and both seem to contribute to environmental stress.

The zero order correlation matrix among the above variables for the years 1981 and 1991 with their statistical significance are furnished in Tables 5a and 5b. The data for Table 5a is based on 1367 villages while that for Table 5b is based on 1593 villages. From these two tables, it can be seen that the nature of the relationship among the variables has remained unchanged in 1981 and 1991, with a few exceptions. The correlation between the area under irrigation (IRR) and the population employed in the nonagricultural sector for both males and females (NAGM81, NAGF81), which was not significant in 1981, turned out to be negatively significant for the females employed in the nonagricultural sector in 1991, (–0.1078). A similar finding is observed with regard to the relationship between CUW and NAGF wherein the relationship that was significant in 1981 (–0.0854) did not turn out to be significant in 1991. The most important finding observed from these two correlation tables is the low level of correlation between literacy levels and the proportions employed in the nonagricultural sector: +0.1384, +0.1057, and +0.1733 in 1981 and +0.1832, +0.0.0652, and +0.1920 in 1991 for men, women, and the total

Table 5a. *Correlation matrix Kota (1981, for all villages N = 1367)*

Variables	*IRR81*	*CUW81*	*MLIT81*	*FLIT81*	*PLIT81*	*NAGM81*	*NAGF81*	*NAGT81*	*POPDEN81*	*POPT81*
IRR81	1 0000	—	—	—	—	—	—	—	—	—
CUW81	0 1519**	1 0000	—	—	—	—	—	—	—	—
MLIT81	0 2277**	-0 1522**	1 0000	—	—	—	—	—	—	—
FLIT81	0 1154**	0 1310**	0 5639**	1 0000	—	—	—	—	—	—
PLIT81	0 2181**	-0 1617**	0 9640**	0 7444**	1 0000	—	—	—	—	—
NAGM81	0 0068	-0 0875*	0 1384**	0 2386**	0 1886**	1 0000	—	—	—	—
NAGF81	0 0154	-0 0854*	0 0802*	0 1057**	0 1019**	0 5760**	1 0000	—	—	—
NAGT81	0 0122	0 0930**	0 1224**	0 2291**	0 1733**	0 9842**	0 6454**	1 0000	—	—
POPDEN81	0 2599**	0 0410	0 2658**	0 1992**	0 2654**	0 2443**	0 2107**	0 2428**	1 0000	—
POPT81	0 1354**	-0 0310	0 3536**	0 3682**	0 3974**	0 3536**	0 1292**	0 3248**	0 3706**	1 0000

Note 2-tailed significant * -0 01 ** -0 001

Table 5b. *Correlation matrix: Kota (1991, for all villages N = 1593)*

Variables	*IRR91*	*CUW91*	*MLIT91*	*FLIT91*	*PLIT91*	*NAGM91*	*NAGF91*	*NAGT91*	*POPDEN91*	*POPT91*
IRR91	1 0000	—	—	—	—	—	—	—	—	—
CUW91	-0 1965**	1 0000	—	—	—	—	—	—	—	—
MLIT91	0 3169**	-0 1359**	1 0000	—	—	—	—	—	—	—
FLIT91	0 1838**	-0 1256**	0 6917**	1 0000	—	—	—	—	—	—
PLIT91	0 2961**	-0 1406**	0 9711**	0 8385**	1 0000	—	—	—	—	—
NAGM91	-0 0131	-0 0631*	0 1832**	0 2793**	0 2289**	1 0000	—	—	—	—
NAGF91	-0 1078**	0 0107	0 0190	0 0652*	0 0378	0 5722**	1 0000	—	—	—
NAGT91	-0 0268	-0 0607*	0 1475**	0 2469**	0 1920**	0 9868**	0 6441**	1 0000	—	—
POPDEN91	0 2360**	0 0102	0 2516**	0 2049**	0 2561**	0 2884**	0 1556**	0 2786 **	1 0000	—
POPT91	0 1241**	-0 0011	0 3022**	0 3506**	0 3406**	0 4025**	0 1367**	0 3813**	0 3963**	1 0000

Note 2-tailed significant, * -0 01 ** -0 001 population, respectively. These coefficients are statistically significant because of the large sample size of villages in the district, 1367 in 1981 and 1593 in 1991. However, the female literacy rate is capable of explaining less than four percent (r-squared value) of the variance in the nonagricultural employment level. Our analysis for the state, taking the district as the unit of analysis, on the relationship between female literacy and employment in the nonagricultural sector in the rural areas, yielded a statistically insignificant correlation coefficient in 1991. One would normally have expected a much stronger relationship between the levels of literacy and employment in the nonagricultural sector at the village or district level, but this is not the case within Kota (Hypothesis 2).

The association between the land area under irrigation and employment is insignificant and positive for 1981 and negative for 1991. It was significant only in the case of female employment in the nonagricultural sector. This indicates that, in recent years, increased diversification in employment tends to be associated with lower land area under irrigation. It is likely that persons employed in the nonagricultural sector may, at least in some cases, neglect intensive cultivation of their lands, because of the higher wages received from their nonagricultural occupations.

A multivariate analysis relating 'culturable waste' (CUW) as the dependant variable, with other selected predictors was carried out for 1991 data. The culturable waste was used as an indicator of the environmental stress variable that demands use of all available area for cultivation or for other utilitarian purposes such as housing. The lower this proportion, the greater will be the stress on the available land area. The predictive factors used were: population density (POPDEN) as an index of demographic pressure, female literacy rate (LITF) as an index of social development, area under irrigation (IRR) as an index of economic development of the agricultural population, and main male workers (NAGM) as an index of occupational diversification. On the basis of the analysis for all villages, the following results were obtained

$$\text{CUW} = 11.609 + 0.851 * \text{POPDEN} - 0.078 * \text{FLIT} - 0.078 * \text{IRR} - 0.042 * \text{NAGM} \quad (1)$$

R-squared = 0.054 with R and all the regression coefficients statistically significant at the level of 0.0001.

To examine the role of population size, the POPDEN variable was replaced by POPT in the multivariate analysis. The following results were obtained

$$\text{CUW} = 12.074 + 0.001 * \text{POPT} - 0.089 * \text{FLIT} - 0.071 * \text{IRR} - 0.042 * \text{NAGM} \quad (2)$$

R-squared = 0.049 with R and all the regression coefficients statistically significant at 0.0001.

The regression coefficients in equations (1) and (2) above are almost the same, except for the population variable where the coefficient for POPT or population size is smaller than that for population density; but both are significant and in the right direction.

The above analysis pertains to all the villages in the district of Kota, irrespective of whether they have a forest or not, and are based on the levels of the predictors and the dependant variables in 1991. It will be interesting to study the effects of the same predictors separately for villages having a declared forest area.

Tables 6a and 6b present the zero order correlation coefficients of selected variables for the villages with declared forest areas (714 and 770 villages in 1981 and 1991, respectively). The proportion of land under forest (FOR) is significantly and negatively associated with CUW, IRR, FLIT, and POPDEN in both the years. The magnitude of the coefficients declined between 1981 and 1991, except in the case of FLIT. NAGM, which was not significant in its association with FOR, became significant in 1991. With occupational diversification, dependance on the forest seems to decline at

Table 6a. *Correlation matrix: Kota (1981; for forest villages N = 714)*

Variables	*FOR81*	*CUW81*	*IRR81*	*FLIT81*	*NMAGM81*	*POPDEN81*
FOR81	1 0000	—	—	—	—	—
CUW81	-0 3114**	1 0000	—	—	—	—
IRR81	-0 3637**	-0 1215*	1 0000	—	—	—
FLIT81	-0 1588**	-0 1460**	0 2711**	1 0000	—	—
NAGM81	0 0575	-0 1402**	0 0496	0 2611**	1 0000	—
POPDEN81	-0 4401**	0 0912	0.3122**	0 2532**	0.2055**	1.0000

Note 2-tailed significant, * -0 01 ** -0 001

Table 6b. *Correlation matrix· Kota (1991; for forest villages N = 770)*

Variables	*FOR91*	*CUW91*	*IRR91*	*FLIT91*	*NAGM91*	*POPDEN91*
FOR91	1 0000	—	—	—	—	—
CUW91	-0 2871**	1 0000	—	—	—	—
IRR91	-0 3962**	-0 1489**	1 0000	—	—	—
FLIT91	-0 1820**	-0 1163*	0 2182**	1 0000	—	—
NAGM91	0 1113*	-0 0982*	0 0253	0 2697**	1 0000	—
POPDEN91	-0 3854**	0 0433	0 2784**	0 2558**	0 2042**	1 0000

Note 2 tailed significant, * -0 01, ** -0 001 the village level. A multivariate analysis relating FOR with other predictors for 1991 led to the following results

$$FOR = 58.50 - 7.94 * POPDEN - 0.80 * CUW + 0.24 * NAGM - 0.63 * IRR - 0.33 * FLIT \quad (3)$$

R-squared= 0.38, which is highly significant. All beta coefficients are also highly significant.

The same set of demographic and developmental variables seem to explain a higher proportion of the variance in the 'forest area' than in the 'culturable waste' in all villages (Equation 1).

INTERPRETATION OF THE RESULTS

The foregoing analysis may be regarded as a first step in understanding the changes taking place at the village level in the context of industrialization and urbanization. The following tentative conclusions can be drawn from the analysis.

1. The level and pace of social and economic development at the village level seems to be significantly influenced by the population size of the village. This is true for social and economic development in 1981 as well as 1991. Separate developmental strategies have to be evolved for the 'very small' and 'small' villages with populations less than 500.
2. Economic and social development seem to move together and adversely affect the proportion of land under 'culturable waste', creating environmental stress. Between 1981 and 1991, the percentage of CUW has declined from a mean of 11.28% to 10.22% of the land area in the villages, indicating a decline in the common property resources at the village level.
3. With social and economic development, the villages with declared forests seem to be adversely affected with respect to their land area under 'forest'. This is indicated by improvements in literacy (FLIT) and IRR. However, in 1991, we found that occupational diversification at the village level has a positive association with FOR. People engaged in the nonagricultural sector in rural areas may not be responsible for depleting the forest land. It cannot be ascertained whether forests have depleted within a given forest area as the necessary data on the density of forests is not available.
4. The multivariate regression analysis revealed that the same developmental variables were able to explain a much larger proportion of the variability in FOR as the dependant variable in forest villages than in CUW in the combined analysis of all the villages (R-squared 38% compared to 5%).

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POPULATION AND ENVIRONMENT INTERRELATIONSHIPS: THE CASE OF NEPAL

Bhim P Subedi[1]

INTRODUCTION

Much has been written about population growth, fertility, and the prescription of technical fix in Nepal (e.g., CBS 1987; 1995; Banister, Thapa 1981; KC Bal Kumar 1995; Gurung 1989; Joshi 1993; Tuladhar, Gubhaju, Stoeckel 1977; HMG/N 1992). Likewise, there is no dearth of literature on the environment, the ecocrisis, and on accusations against human actions (e.g., Eckholm 1976; NPC/IUCN 1992; HMG 1993; WECS 1990). However, our understanding of population–environment interrelationships in Nepal is very poor, and an attempt to understand the complexity has only just begun. This paper attempts to provide a national scenario of population growth and its impact on the environment. It begins with the conceptual aspects of population–environment interrelations and then presents the case of Nepal. The growth of population is discussed first, followed by regional disparity, land use changes, deforestation, and changing crop production and cropping intensity. In spite of the overwhelming impression of the negative impacts of population growth on the environment, there are indications of positive changes in the country. The extent of environmental changes taking place in the country, however, needs to be assessed in the context of historical background, its geology, and the changing access to resources.

Meeting human needs and enhancing the quality of life, i.e., development, in the context of growing population, tends to put increasing demands on the environment (WCED 1989). It should be realized that the limits of sustainability have structural as well as natural origins (Redclift 1991). Chambers (1986) pointed out that environment and development are the means, and not the end, in themselves. Thus, there is a clear link between population, environment, and sustainable development. Maintaining a balance between

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the productive potential of the ecosystem with minimal or no damage to its environment and the increase in human welfare, which has to cope with increasing numbers, is a very critical issue facing contemporary society. Focus on increase in production to cope with increasing population should ensure that production itself does not degrade resources beyond their regenerative capacity.

THE INTERRELATIONSHIPS

The interrelationship between population and environment is complex. This complexity is further reinforced by the numerous dimensions of each factor; and the impact is mutually reinforcing. People modify their environment; population, in turn, is affected by changes in the environmental conditions. While these interrelationships unfold over time, the socioeconomic context plays an important role in mediating them.

Misunderstandings surround our knowledge of the interrelationships between population and environment. Attempts to understand the interrelationships have just begun (Ehrlich, Ehrlich, Daily 1993; ADB 1991; ESCAP 1993). The general impression is that, over time, population increases, and this increase pressurizes the environment and its resources beyond their regenerative capacity. There is a presumption here that the impact of population growth is always negative. Such notions are too simplistic and represent a distortion of reality.

In recent years, there has been increased realization that the issue of population involves not only its size but also its structure, quality, and pattern of distribution. Population size alone is not responsible for environmental changes; consumption levels, utilization patterns, and technologies play a vital role in the overall environmental changes in an area. This, in turn, is related to the socioeconomic structure of the society. In a similar fashion, political, social, and economic institutions also play an important role in the overall changes of the environment.

Existing literature offers two major viewpoints about the precise relationships between population growth and environmental changes. Ehrlich, Ehrlich (1990) take a view that environmental deterioration is the direct consequence of population growth. They argue that population growth causes a disproportionate negative impact on the environment and that redistributing population would be a dangerous pseudo solution to the population problem. In their earlier publication, Ehrlich, Holdren (1971) suggested that the total impact of a society on the ecosystem can be expressed as

$$I \quad P * F$$

where I stands for total impact; P for population size; and F for impact per capita

Commoner, Corr, Stamler (1971) are of the view that though population is an important contributor to environmental deterioration, it is not the major detriment to environmental crisis. For them, other variables such as technology play a more significant role in the ecological crisis. Accordingly, technological changes are more important than mere population size and the impact per capita. Thus, the interrelationship of population and environment can be expressed as

$$I = P * A * T$$

where I is a measure of environmental impact, P stands for an index of population, A is per capita consumption, and T is a measure of environmental damage caused by the technology used in supplying each unit of consumption.

DIMENSIONS OF COMPLEXITY

Figure 1 attempts to summarize the interrelationships between population and environment. The left panel shows population and its various dimensions whereas the right panel shows selected dimensions of environment. The issue of population is not only related to its quantity, i.e., size, structure, growth, and distribution, but also with its quality. The indicators of the quality of population include the level of education, health, technical skills, and tastes (values) of the people, which may have developed through culture. In addition, the behavioral aspects of population including fertility, mortality, nuptiality, and migration have a direct ramification on the utilization of the environment.

Environment, in general, is translated as a natural resource base. In the context of developing countries such as Nepal, the most commonly used environmental resources include land, forests, pastures, and water. The quality, coverage, and level of utilization of these resources is as important as their magnitude. The middle panel specifies the critical variables from which the impact and the mutually reinforcing relationship between population and environment materializes. This signifies that the use/misuse, utilization, and the assessment of carrying capacity is manifested through existing technology, affluence/poverty, consumption levels, and efficiency (or misconduct) of existing social, economic, and political institutions.

The lower middle panel specifies the attributes of urban environment. Commonly observed urban environmental issues in countries such as Nepal include space, slums/squatters, water supply, electricity, waste disposal, and various kinds of pollution. Whereas the quality of urban environment is influenced by intermediate variables of the middle panel, i.e., technology, consumption, affluence, and institutions, it is also a manifestation of the size and pattern of distribution of the population of the country. The level of ur-

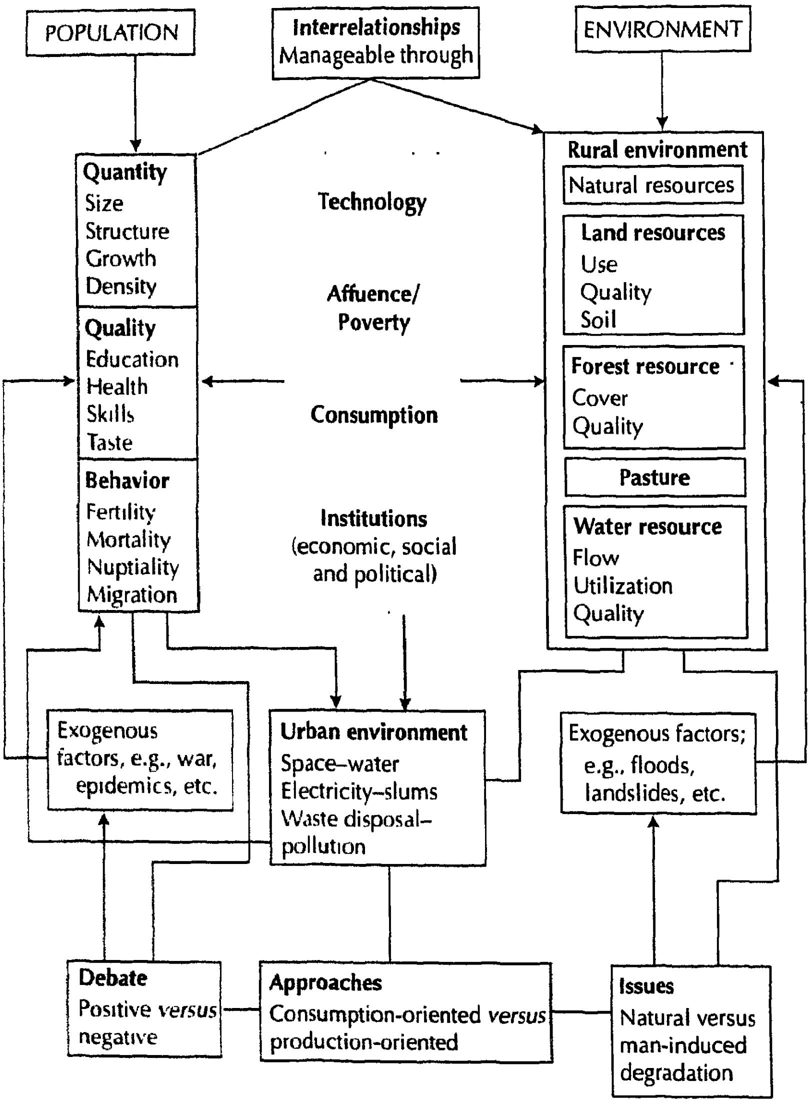

Figure 1. *Population and environment relationships, a schematic diagram*

banization, in turn, helps modify fertility behavior and the social quality of the population. While the relationship between population and environment is interactive, it is also dynamic, and any change in the components of each of these variables will have a corresponding impact on other variables. Similarly, an introduction of a new technology and a change in the consumption level and institutional commitment will bring in significant changes in the existing relationships between population and environment.

Further complexity arises when exogenous factors enter this realm. Disease, epidemics, wars, and political turmoil bring instability into the existing structure of the population component, and thereby the nature of relationship with the environment. Likewise, natural disasters such as floods, landslides, earthquakes, and volcanoes function as the exogenous factors for the environmental component. These exogenous impacts severely constrain the existing status of the environmental resource base and, in turn, limit its carrying capacity. This upsets the existing population–environment relationships and, thus, inhabitants are compelled to readjust.

There are various unsettled issues and approaches in the literature about population, its behavior, and the nature of environmental problems. Scholars such as Simon (1981) argue that because people are the ultimate resource, there is little or no reason to be pessimistic about population growth. Similarly, scholars working through the production-oriented approach take the view that population growth is not necessarily bad (Boserup 1968), simply because the new generation also brings in talent and earning hands with it.

On the other hand, there are those who are not very optimistic about the growth of population and its impact. They regard population growth as a problem, taking into account the changes occurring in the world food situation over the years. Accordingly, they argue that as the food situation has reached a precarious state, in the long run substantial and further growth is considered unsustainable (Bongaarts 1993; Ehrlich, Ehrlich 1990).

Based on the Malthusian perspective, some scholars adopt the consumption-oriented approach to population and warn that any additional number is a burden on humanitarian grounds. Furthermore, the issue of 'who is to blame' takes us to the ideological and methodological debate which is beyond the scope of this paper. The study of human–environment interrelations is concerned with questions of whether humans are the sole agents of environmental degradation and, if not, how much of degradation can be directly attributed to human action and how much to that of natural processes. These issues are very complex. This is more so in the context of developing countries characterized by stagnant economies, rapid population growth, and physical landscapes dominated by fragile mountains of recent origin.

THE CASE OF NEPAL

Nepal is an interesting case of very rapid population growth accompanied by severe environmental degradation. It constitutes an area of 147 181 km^2, characterized by three distinct ecological regions, namely, the mountains, the hills, and the *tarai* (plains) (Figure 2). While from historical times, people from the north as well as the south, have settled on the hills; settlement in the *tarai* is mostly a phenomenon of the last few decades. Frontier settlement

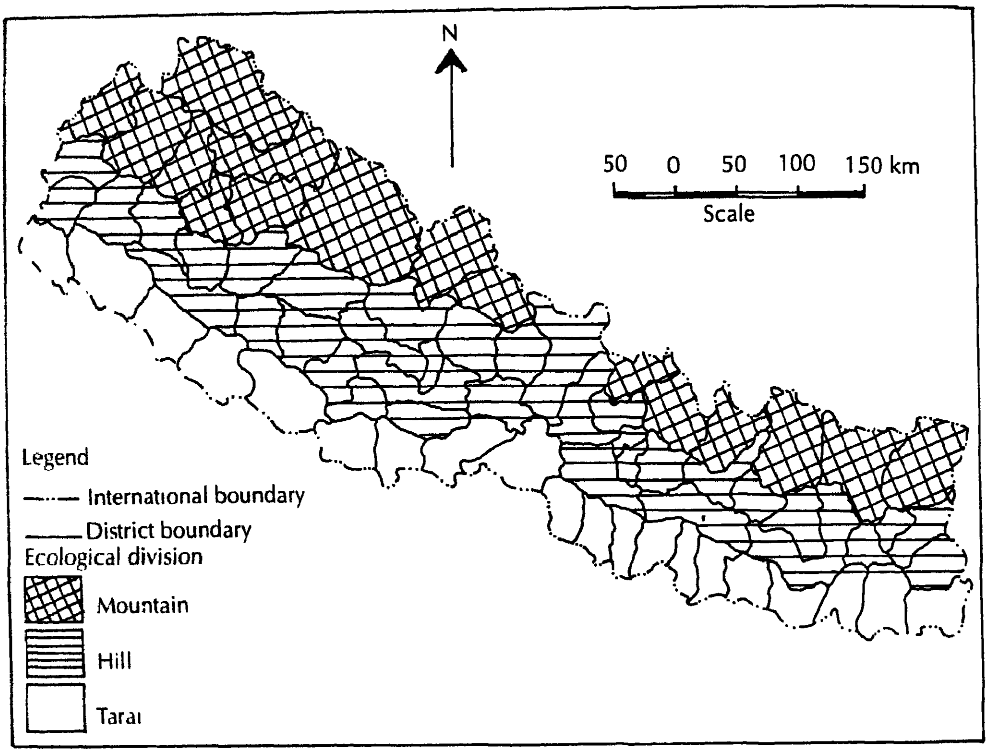

Figure 2. *Ecological regions of Nepal*

and colonization in the *tarai* is also an expression of population growth within and outside the *tarai* regions as well as in the states of the adjoining country (Conway, Shrestha 1981) .

As 90% of Nepal's people live in rural areas.and agriculture is their mainstay, people have constantly looked for additional land for expanding agricultural areas to support the increasing population as well as to improve their economy. In this process, people have put heavy pressure on the local environment, which has suffered as a consequence. As early as the 1970s, statements such as 'Nepal faces the world's most acute national soil erosion problem' and 'the continuation of present trends (of deforestation) may lead to the development of a semidesert type ecology in the hilly regions' were made (Eckholm 1976: 77, 81) Though these are rather extreme, they reflect the seriousness of the problem. In this context, the following sections provide a glimpse of the growth of the Nepali population and its impact on the environment with particular reference to the *tarai*.

GROWTH OF POPULATION

For most part of history, the population size of Nepal was small and the growth was slow. The earliest figure available is for 1911 which shows a population size of 5.6 million. The following two decades record a decline in the population size in the country. This apparent decline has been attributed to World War casualties and under-reporting, especially that of adult males, for the fear of conscription into the army. The figures of 1941 show an increase in the total volume for the first time. It is to be noted that figures up to 1941 are estimates, and details on age, sex, and other characteristics were not reported.

Over the last few decades, the population of Nepal has grown more rapidly than ever before. The first 'scientific' census, 1952–54, recorded a total population of 8.26 million in the country with an annual growth rate of 2.3%. The successive censuses have since then recorded a continuous increase in the size of the population in the country (Table 1). The actual size has more than doubled between 1952–54 and 1991.

Growth rates have been consistent at over two percent per annum (except in the 1961 census) during these decades. The most recent census, i.e., 1991, enumerated a total of 18 491 097 persons in the country with the intercensal growth rate of 2.1%. This means that if this growth rate continues there will be another 'Nepal' before 2024. Moreover, the official estimates suggest that the population reached 21.13 million in 1996 (CBS 1994).

Table 1. *Nepal: growth of population*

Census year	*Total population*	*Annual growth rate (%)*	*Approximate doubling time (years)*
1911	5638749	NA	—
1920	5573788	-0.13	—
1930	5532574	-0.07	—
1941	6283649	1.16	60
1952-54	8256625	2.30	31
1961	9412996	1.65	42
1971	11555983	2 07	34
1981	15022839	2 66	26
1991	18491097	2 10	33

Sources CBS (1987, 1993)

REGIONAL DISPARITY

Rapid increases in the size and rate of growth of the nation's population, in general, is an important issue. More important in the context of Nepal is the disparity in growth by geographical regions. This is clearly indicated by the changes that occurred over successive periods in the proportional share of total population and density differential by the regions. Of the three geographical regions, the hills had the majority population in 1971. This was followed by the *tarai*; the gap between the hills and the *tarai* was very wide (Table 2; Figure 3). By 1981 the gap had been narrowed significantly but the hills still

Table 2. *Nepal: changing regional proportion and density of population (1971–1991)*

Geographical regions	*Percentage of total population*			*Density of population (per km^2)*		
	1971	*1981*	*1991*	*1971*	*1981*	*1991*
Mountains	9 9	8.1	7.8	22	25	28
Hills	52.5	47.7	45.5	99	117	137
Tarai	37 9	43.7	46 7	129	193	254
Nepal	100 0	100.0	100.0	79	102	126

Sources CBS (1975, 1984, 1994)

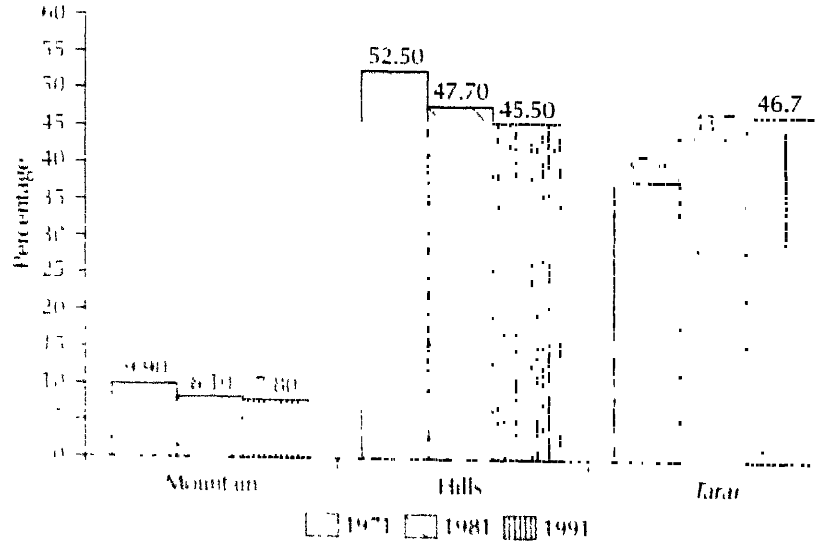

Figure 3. *Changing regional proportion of population*

dominated. By 1991, for the first time in history, the *tarai* emerged as the region with the highest percentage of the nation's population. The hills trailed behind with 45.5%. The share of the mountain regions has continuously declined, from 9.9% in 1971 to 7.8% in 1991.

While the regional proportion has changed over the last three decades, a more pronounced change has occurred in the regional man–land ratios. The crude density has increased for the country as well as for all the geographical regions between 1971 and 1991. The extent of increase is more pronounced in the *tarai* than in the hills and the mountains (Table 2; Figure 4). Between 1971 and 1991, the crude density in *tarai* has increased by 97%, i.e., from 129 persons per square kilometer in 1971 to 254 persons per square kilometer in 1991. Corresponding changes in the hills and the mountains during the same period has been only 38.4% and 27.3%, respectively. This indicates that the impact of population growth is most visible in the *tarai* as compared to other regions of the country.

The distribution of both the total and the cultivated land is uneven. The hills occupy a major proportion of total land, followed by the mountains. There is a clear regional difference in the proportion of cultivated land, the relative stress of population, and the consequent physiological density. The *tarai*, which occupies 23% of the total area, accounts for 56% of the country's cultivated area. As a result, its physiological density is the lowest in the country, despite the fact that it ranks highest in crude density. The hills, which support 45.5% of the population, occupy only 37% of the cultivated land.

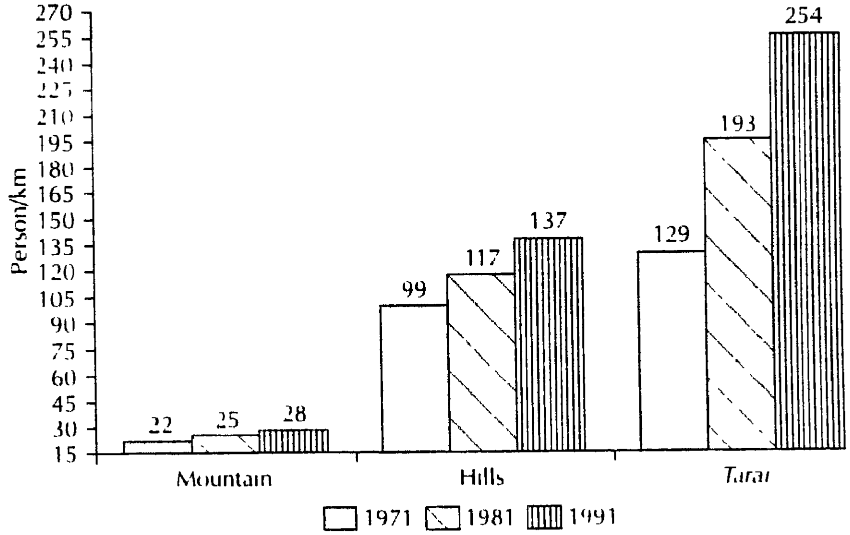

Figure 4. *Changing density of population*

Accordingly, the physiological density is 960 persons per hectare in the hills, i.e., the highest in the nation. The mountain region ranks second with 890 persons per hectare and occupies only seven percent of the cultivated land. It is interesting to note that even though the arithmetic density in the *tarai* has increased by 97% over the last 20 years, its physiological density per hectare is still 300 persons less than that of the hills (Table 3).

Reliable longitudinal data on cultivated land are not available. The recent Agriculture Sample Census of Nepal (1991) demonstrates that average per capita cultivated land is 0.127 hectares (ha). Both the hills and the mountain regions have per capita cultivated land below the national average. Only in the *tarai* region, this value is above the national average (Table 3). A study estimates that under the current production system, a farmer needs 0.15 hectares of land to meet average calorie intake (Pant 1992). If this amount is to be applied to the current distribution of population with an assumption of land being the main source of calorie intake, the deficit for the nation works out to be 420 000 ha for the nation. While the hills appear to have a deficit of 383 000 ha, the corresponding deficit in the mountains happens to be 53 000 ha. On the contrary, the *tarai* will have a surplus of around 16 000 ha. Apparently, this arithmetic of surplus and deficit, further supported by the malaria eradication program and the resettlement scheme of the 1950s in the *tarai*, lies at the heart of escalating hill to *tarai* migration in the country.

INTERNAL MIGRATION

One of the responses of the apparent demographic change is internal migration. The last four censuses have shown an increasing trend of lifetime internal migration. The hills and the mountains have remained the main place of origin for more than 90% of the population. Likewise, the *tarai* has become

Table 3. *Nepal: regional disparity in land and related ratios*

Regions	*Total area*		*Cultivated area*		*Ratios (density)*	
	Area (km²)	*Percentage*	*Area (ha)*	*Percentage*	*Nutritional (persons/ha)*	*Cultivated area per capita (ha)*
Mountains	51817	35 2	163093	6 9	890	0 113
Hills	61345	41 7	878837	37 4	960	0 105
Mountains/hills	113162	76 9	1041930	44 3	950	0 106
[illegible]	34019	23 1	1311785	55 7	660	0 152
Total	147181	100 0	2353715	100 0	790	0 127

[illegible] 1987 1993 1994)

the major destination for the majority of the migrants. Between 1981 and 1991, the overall regional pattern of migration has remained consistent although some changes have occurred in the proportionate share of each of the regions over the two censuses. The *tarai* has continued to be the main receiving area and its proportion has increased over time (Table 4). On the contrary, the share of both the hills and the mountains has further decreased in terms of receiving internal migrants.

Of the total population, 6.9% comprised internal migrants in 1981, while this proportion increased to 7.7% in 1991. Of the total migrants in 1981, 61% originated from the hills and 30% from the mountains. The share of the *tarai* has been the lowest. By 1991, the hills become the place of origin for 72% of internal migrants (Table 4). While the proportion of the mountains has decreased from 30% to 14%, the proportion of the *tarai* significantly increased in 1991. This suggests that the hills have experienced the highest net loss and that the *tarai* is characterized by a net gain.

Of the total employed among 10 years of age and over, 81% fall in the agricultural sector, according to the 1991 census. The corresponding percentage for 1981 was 91%. Being an agricultural country, the stream of migration is directed mainly from rural to rural areas. Rural–urban migration has become an emerging issue (Sharma 1989; 1993; Subedi 1988), but its volume is still very low. The fact that per capita cultivated land is lowest in the hills and is grossly inadequate to maintain household economy clearly demonstrates the increasing flow of hill to *tarai* migration. In addition, according to the 1991 census, about 40% of the economically active population worked for less than eight months in 1990. This is indicative of underemployment and, thus, the search for better opportunities is imperative. One of the consequences of this whole process of population growth and migration is land use change and deforestation in general, and in the *tarai*, in particular.

Table 4. *Nepal: percentage of lifetime internal migrants (1981 and 1991)*

Geographical regions	*In-migrants (%)*		*Out-migrants (%)*	
	1991	*1981*	*1991*	*1981*
Mountains	2.8	05.2	14.2	30.3
Hills	18.8	20.4	72.0	61.3
Tarai	78.4	77.4	13.8	08.4
Nepal	100.0 (1418206)	100.0 (1038862)	100.0 (1418206)	100.0 (1038862)

Note. The figure in the parenthesis indicate the volume of internal migration
Sources CBS (1984, 1994)

LAND USE CHANGES

At present, major productive land use categories in Nepal include forests, agricultural lands, and pastures. Forests, including shrubs, occupy the highest proportion, followed by agricultural land (Table 5). A large proportion of the land surface is occupied by rocky land. Rocky surfaces, including snow-capped areas, occupy approximately one-sixth of the national territory. Land used for pastures comprises 11.8% of the land but most of it is of low quality.

Availability of comparable data is the main problem one faces while assessing the extent of change that has taken place over recent years. This is because different sources present different data on the total land use pattern. In any case, with the growth of population, significant changes in land use have taken place over the years. The most notable change has taken place in agricultural and pasture lands and forests. The Sixth Plan (1980–1985) reports that in 1974 the total land under agriculture was 16.5%. The same document also reports that in 1979 the total land under agriculture reached 22.2%, an increase of 5.7% from 1974. Similarly, according to the Eighth Plan (1992–1997), agricultural land accounts for 26.5% of the total area of the country. This is indicative of the significant change in bringing other land uses under agriculture. Increase in total agricultural land cannot be consid-

Table 5. *Nepal: land use pattern (1986)*

Types of land use	*Total area (ha)*	*Percentage*
Agriculture	3954915	26.6
Cultivated	2968017	20.0
Uncultivated	986898	6.6
Forest	6306460	42.4
Forest land	5618052	37.8
Shrubs	688408	4.6
Pastures	1757345	11.8
Rocky surface	1966090	13.2
Others	870232	6.0
Snow-capped areas	506317	3.4
Stone/sand	322428	2.3
Steep terrains	5575	0.0
Barren land	13414	0.1
Lake/pond	11584	0.1
Urban area	10914	0.1
Total	14855042	100.0

Source NFC 1992

ered either positive or negative in itself. However, some of the recent increases in agricultural land are slopes and marginal lands, which are less productive and more environmentally sensitive, implying that the direction of change is not in congruity with keeping a better harmony between the environment and population.

Change in the area under agriculture is reflective of population growth and ever-increasing needs. Average land holding of about 50% of the households with an average family size of 5.5 persons is less than 0.5 ha and, hence, not sufficient to meet their basic requirements (Pant 1992). There is, thus, a strong demand for additional land for agriculture. Whereas bringing other land uses under cultivation has remained the main strategy for coping with population growth thus far, the future prospect of land expansion for agriculture is minimal primarily in the hills and the mountains. Reports suggest that it has already reached its limits (Banskota 1992). It is to be noted that even the better lands in the *tarai*, the only frontier left, have been brought under cultivation. This insinuates an incomplete and negative picture. Some positive changes such as intercropping, multiple-cropping, intensification, and an increase in cropping intensity have also taken place.

Whereas agricultural land has increased, the proportional share of pasture land has declined. A cursory examination of the government's plan documents clearly justifies this. Of the total land resource, 12.7% was used as pasture land in 1974. Data for 1979 report that the same proportion of total land resources was devoted for pasture lands. A decline in the total percentage of pasture lands is evident after 1979. By the Eighth Plan, the total pasture land comprised of only 11.8% of the total land of the country, showing a decline of 0.9% (Table 5). This is primarily attributed to its conversion into agricultural land over the years.

Structurally, the landscape of the country is composed of young mountains. Thus, the terrain is naturally fragile, erodible, and inaccessible. More importantly, human factors have further accelerated this process and a report indicated that approximately 53% of the landslides in Nepal were man-made (NPC 1985). Human misuse, such as cultivation in slopes greater than 30° and terracing without proper drainage, has further accelerated the process of erosion and landslides, and has collectively made the land use and utilization pattern dynamic.

DEFORESTATION

In a traditional society where agriculture is rather a way of life, population growth has consecutively accompanied increased demands for agricultural land, fuelwood, and pastures. All of these have singly, as well as collectively, resulted in deforestation and degradation of forests This process has accelerated after the 1950s mainly for three reasons: (i) rapid rate of population growth; (ii) initiation of the resettlement program following the malaria eradication program, which opened up the floodgate; and (iii) the nationalization of forests traditionally managed by the community in 1957. The nationalization was accomplished when the managerial capacity of the government was rather weak. All this collectively initiated the tragic course of action on forest lands and ultimately led to the process which is, to use a metaphor, *the tragedy of the commons.* Faced with poverty and growing numbers, individual households rushed to exploit forests for agricultural land, fodder, pastures, and fuelwood. In the process, societal goals of conservation and environmental management were pushed to the periphery.

Available data are often in conflict about the direction of change in areas under forests. The Sixth Plan (1980–1985) recorded 29.1% of the total land of the country as forest land while the Eighth Plan documented it at 42.2% (Table 5). Earlier studies have reported heavy deforestation in the *tarai* during the 1960s and the 1970s, a process that has not stopped even though the extent has decreased. From 1950 to 1985, 103 968 ha of forest land were cleared for settlements (Bhatta 1992). The Master Plan for the Forestry Sector (FSMP) estimated that the average annual loss of forest area from 1978/79 to 1984/85 was 7566 hectares or 0.14% of the natural forest (HMG/ADB/FINNIDA 1988). On the other hand, effective reforestation was hardly 8.7% of the reduced forest area (Bhatta 1992).

Degradation and change in the crown cover of forests are important aspects of the Nepalese natural landscape. Such degradation is more serious in the hills. The FSMP (1988) demonstrates that from 1979 to 1985, approximately 219 300 ha of forest land was degraded due to overcutting to meet the increasing demands of people and livestock. As of 1985/86, the crown cover is less than 70% for more than 80% of the forests and only 15% of the total forests have a crown cover of 70–100% (Mishra 1994). LRMP (1986) reported that between 1964 and 1985, area under forest cover was reduced by 22 800 ha per year. The loss of forest land is normally attributed to conversion into cultivated land, cutting for fodder and fuel wood (Bajracharya 1983), and occasional fires set by the herders.

DEFORESTATION IN THE *TARAI*

The 1960s and early 1970s were mainly characterized by heavy forest clearance especially in the *tarai* areas. During the period 1964–74, a total of 77 700 ha of forest land was cleared for official settlement and during the same period an additional amount of 237 600 ha was encroached by spontaneous settlements (NPC 1980). The depletion of forests was estimated at the rate of 3.9% per annum up to the end of 1980s (FSD 1993). Compared with the *tarai*, less forest land has been lost in the hills primarily for two reasons: (i) the scattered nature of the forests there; and (ii) the lower productivity of the forest land. Nonetheless, degradation of forest resources is still severe in areas in the hills where the man–land ratio is very high. Expansion of land for cultivation has been the main reason so far for the depletion of forests. A report suggested that during the period 1975–1980 forest area declined by 700 000 ha, while cultivated land increased by more than 800 000 ha during the same period (NCP 1982).

Forest clearing is difficult to avoid given the increasing population in the adjoining hills and the lack of income-generating opportunities there. With the opening up of infrastructure in the previously inaccessible areas in the *tarai*, the inflow of population from the resource-poor hill and mountain areas became imperative. Recent changes in the forest area between 1978/79 and 1990/91 exacerbate the impact of population growth on its environment. Of the three regions, the *tarai* is the area where most of the deforestation has been taking place and these deforested areas continue to be converted into agricultural land. Until recently, the extent of forest depletion increased gradually from the west to the east (Gurung 1989). This, in turn, also reflected the regional concentration of population and the higher rate of growth of population in the east as compared to the west. More recently, this trend has changed and the extent of deforestation has been more pronounced in the western regions as opposed to the eastern ones (Figure 5; Table 6). Population, too, has increased rapidly in these areas in recent years

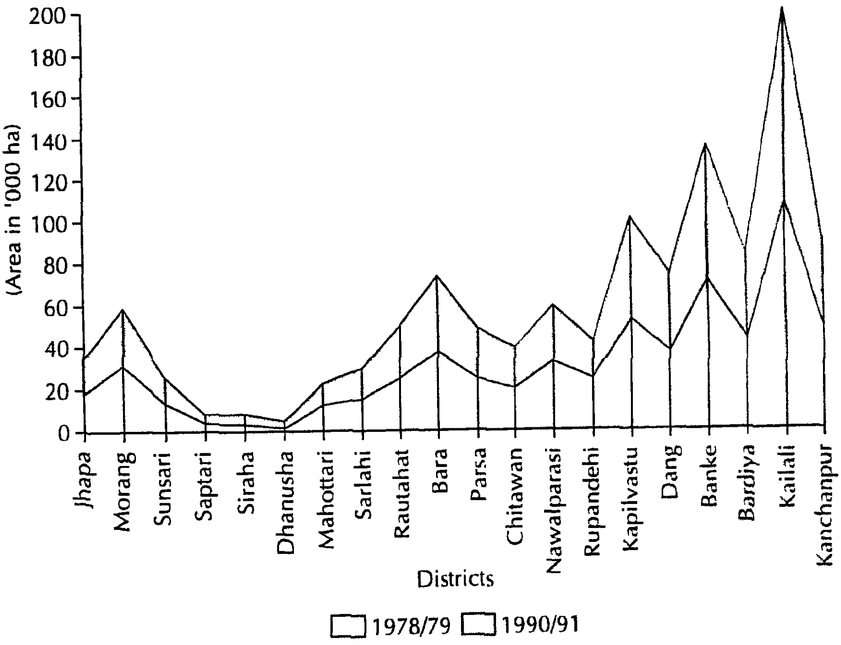

Figure 5. *Change in forest cover in the plains of the tarai districts*

Table 6. *Nepal: change in forest area in the plains of the* tarai *districts (1978/79–1990/91)*

Name of the district	Forest area in the plains (ha)		
	1978/79	*1990/91*	*Change (%)*
Jhapa	19100	15000	-21.5
Morang	31900	26700	-16.3
Sunsari	14800	11100	-2.5
Saptari	5100	3300	-35.3
Siraha	4100	4300	+4.9
Eastern *tarai*	75000	60400	-19.5
Dhanusha	2000	2600	+30.0
Mahottari	12800	9400	-26.6
Sarlahi	15700	13500	-14.0
Rautahat	25400	24100	-5.1
Bara	38200	35400	-7.3
Parsa	25700	23200	-9.7
Chitawan	20900	18500	-11.5
Central *tarai*	140700	126700	-10.0
Nawalparasi	33900	25600	-24.5
Rupandehi	25600	16000	-37.5
Kapilvastu	54300	46600	-14.2
Western *tarai*	113800	88200	-22.5
Dang	38000	36400	-4.2
Banke	72800	63100	-13.3
Bardiya	44100	38700	-12.2
Midwestern *tarai*	154900	138200	-10.8
Kailali	109900	93800	-14.7
Kanchanpur	51000	38600	-24.3
Far-western *tarai*	160900	132400	-17.7
Total	645300	545900	-15.4

Source FSD (1993)

(Table 7). According to recent data, forests cover 37% of the total land in the country. The Forest Survey Division (FSD) has recently estimated the forest resources of the 20 *tarai* districts. Accordingly, the total forest area in the *tarai* is 1.4 million ha. Of the total, 546 000 ha (38.84%) lie in the plains and the hills occupy 621 500 ha (44.22%). The remaining land is included in the conservation area. Between 1978/79 and 1990/91, a total of 99 400 ha of forest land was lost in the plains of *tarai*. This implies that the forest area in the plains of the *tarai* declined from 645 300 ha in 1978/79 to 545 900 ha in 1990/91 (Table 6, Figure 5). In the plains, the most recent rate of deforesta-

Table 7. *Intercensal change in population in the tarai districts (1971–1991)*

Name of the district	*Population (1971)*	*Growth rate (1971–1981)*	*Population (1981)*	*Growth rate (1981–1991)*	*Population (1991)*	*Growth rate (1971–1991)*
Jhapa	229561	7.37	479743	2.13	593737	4.8
Morang	293639	5.99	534692	2.33	674823	4.2
Sunsari	238312	3.69	344594	2.96	463481	3.4
Saptari	292108	2.61	379055	2.06	465668	2.4
Siraha	302212	2.17	375358	2.05	460746	2 1
Eastern *tarai*	1355832	4.44	2113442	2.30	2658455	3.4
Dhanusha	330501	2.69	432569	2.29	543672	2.5
Mahottari	298346	1.91	361054	1.98	440146	1.9
Sarlahi	265634	4.06	398766	2.12	492798	3.1
Rautahat	256238	2.61	332526	2.19	414005	2.4
Bara	233330	3.13	318957	2.65	415718	2.9
Parsa	202062	3.42	284338	2.70	372524	3.1
Chitawan	183588	3.46	259571	3.12	354488	3.3
Central *tarai*	1769699	3.00	2387781	2.39	3033351	2.7
Nawalparasi	183973	5.18	308828	3.45	436217	4.3
Rupandehi	243272	4.44	379096	3.20	522150	3.8
Kapilvastu	205154	2.75	270045	3.20	371778	3.0
Western *tarai*	632399	4.15	957969	3.28	1330145	3.7
Dang	186507	3.57	266393	2.85	354413	3.2
Banke	130476	4.53	205323	3.30	285604	3.9
Bardiya	102741	6.61	199044	3.77	290313	5.2
Midwestern *tarai*	419724	4.69	670760	3.27	930330	4.0
Kailali	135982	6.40	257905	4.83	417891	5.6
Kanchanpur	68842	8.98	168971	4.23	257906	6.6
Far-western Tarai	204824	7.34	426876	4.60	675797	6.0
Total	4382478	4.03	6556828	2.75	8628078	3.4

Sources. CBS (1975; 1987; 1994)

tion is estimated at 1.3% (APROSC/JMA 1995). This is an improvement over the Master Plan for the Forestry Sector of Nepal which estimated the deforestation rate of 3.9% between 1978/79 and 1985/86.

Degradation of existing forest is also an equally important issue in the *tarai*. Apart from cutting forests for agriculture, a large amount of trees have been cut annually for fuelwood, as firewood is the major source of energy. According to a report, almost 80% of the energy consumed domestically came from fuelwood in 1992/93 (WECS 1994). An earlier publication indicated that due to increased energy demand, forests around the village have been cut and, therefore, walking time to fetch firewood takes half a day or more (Banister, Thapa 1981). This had not changed much in the 1980s and the 1990s. The increase in population continued. While it was more pronounced in the eastern *tarai* earlier, it picked up in the western regions lately. The annual growth rate of population for mid-western and far-western *tarai* exemplifies this (Table 7).

CROP PRODUCTION AND CROPPING INTENSITY

With the growth of population, important changes in crop production and cropping intensity have taken place in the last two decades. These positive changes have been overlooked in the face of environmental crisis. Likewise, contrary to what has been advocated by extreme environmentalists, not only have areas cultivated for foodgrains increased, but the production of foodgrains has also increased at rates higher than the rate of population growth (Table 8). The production of cereal crops increased by more than 52% between 1981 and 1991. The hills have shown the maximum increase in production, in number, and in percentage. This pattern is followed by the mountains as well, implying that the *tarai* has had the lowest increase. This increase parallels the physiological density of the regions. The regions which show the highest physiological density, i.e., the hills, have the highest increase. Similar increases have taken place in the production of cash crops as well. In terms of productivity, however, there are mixed outcomes. Reports suggest that while productivity of some crops has declined, it has increased or remained stable for others (Acharya 1993; Banskota 1992).

Population growth and production increase are also accompanied by increases in cropping intensity. Between 1981 and 1991, cropping intensity increased by 80% in the *tarai* districts (Table 9). More importantly, this increase

Table 8. *Growth in cereal and cash crop production*

Ecological regions	Cereal crop production ('000 mt)			Cash crop production ('000 mt)		
	1981	1991	Change (%)	1981	1991	Change (%)
Mountains	155 1	255 2	64 5	68 8	151 2	119 6
Hills	1152 8	2174 9	88 7	201 4	430 5	113 8
Tarai	2521 1	3398 4	34 8	572 8	1361 4	137 7
Nepal	3829 0	5828 5	52 2	843 0	1943 1	130 5

Sources CBS (1985), DFAMS/Nepal (1992)

Table 9. *Nepal: cropping intensity in the tarai districts (1981 and 1991)*

Name the district	*Cropping intensity*		
	1981	*1991*	*Change (%)*
Jhapa	1.16	1.65	42.2
Morang	1.55	1.89	21.9
Sunsari	1.61	1.73	7.5
Saptari	1.49	1.59	6.7
Siraha	1.63	1.85	13.5
Dhanusha	1.24	1.71	37.9
Mahottari	1.71	1.85	8.2
Sarlahi	2.00	1.90	-5.0
Rautahat	1.80	1.96	8.9
Bara	1.71	1.81	5.9
Parsa	1.88	1.77	-5.9
Chitawan	1.80	2.21	22.8
Nawalparasi	1.64	1.66	1.2
Rupandehi	1.75	1.66	-5.1
Kapilvastu	1.39	1.55	11.5
Dang	1.91	1.85	3.1
Banke	1.60	1.48	-7.5
Bardiya	1.60	1.81	13.1
Kailali	1.92	1.87	-2.6
Kanchanpur	1.60	1.90	18.8

Source. CBS (1993).

is remarkable in the Jhapa, Dhanusha, Chitawan, and Morang districts. With the exception of Dhanusha, these districts also exhibit population growth rates that have been consistently above the *tarai* average. Of all the districts, Chitawan has the highest cropping intensity; this is also the area where the first resettlement scheme for the *tarai* was launched in the 1950s.

This increase in production of both the cash and cereal crops in excess of population growth rate and increase in the cropping intensity can be taken as positive aspects of population growth. This is in the context of the traditional form of agriculture with low level of agricultural inputs and limited irrigation facilities.

CONCLUSION

The population–environment relationship is complex and mutually reinforcing. In the context of Nepal, attempts to examine the overall impact of population growth on its environment is, at best, indicative of the trend because of the data problem. Longitudinal data are not available, especially on the issues of environment and the available cross-sectional data are inconsistent. Different sources present different and, often, conflicting data. Furthermore, the tendency of dealing with population and environment in isolation for long has resulted in the poor understanding of imperatives of population growth and mountain specificities (Banskota, Joddha 1992) on the basis of which the Nepalese people make decisions on the use of their environment.

With the growth in population whose livelihood is primarily based on the traditional form of agriculture, significant environmental changes have taken place in Nepal over the last few decades. Changes in land use, in general, and forest cover in the *tarai*, in particular, are clear examples of this. Changes that have taken place have had both negative and positive impacts. While the negative changes are well verbalized, increases in crop production and cropping intensity at rates much higher than that of population growth are positive indications. The interpretation of environmental changes must be based on correct assessments (Shrestha 1993), and should be made in the context of in-built geomorphic processes and imperatives imposed by the fragile mountains and long-standing coping strategies (Subedi 1995) of the mountain people.

Several micro-level studies have also reported positive aspects of the change – better management of land in the Khumbu areas and levels of soil erosion that are not as bad as reported (Byers 1986); efficient management of pastures in the mountains (Shrestha, Manandhar 1977); the not so intense deforestation and depletion of forests in the middle hills (Mahat 1986); occupational multiplicity in eastern Nepal (Subedi 1993); and innovative responses to population pressure in the eastern hills (Dahal 1983). The rate of forest depletion at the regional level has improved to 1.3% (FSD 1993) from the 3.9% estimated earlier (HMG/ADB/FINNIDA 1988). It is important that evidence from micro-level studies be linked with the macro-level generalized studies in order to better understand the interrelationships between population and environment in Nepal.

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FUELING THE WORLD'S LARGEST POPULATION AND A FAST-GROWING ECONOMY: THE CHINESE EXPERIENCE

Yingzhong Lu[1]

POPULATION GROWTH

China is the most populous country in the world. In spite of a vigorous family planning and birth control program, the Chinese population has more than doubled since 1952, and reached an astonishing 1.2 billion in 1995. The increase in population, within a period of 15 years, from 1980 to 1995 amounted to 220 million nearly equivalent to the population size of the entire US! Table 1 presents the total population increase and the percentage by rural and urban residence in the People's Republic of China (PRC), excluding the population of Hong Kong, Macao, and Taiwan (see Figure 1). In Table 2, the annual birth rate, death rate, and the natural (net) growth rate of the Chinese population are indicated. It should be noted that although the birth rate dropped substantially after 1975, when the birth control policy was put into effect, the net growth rate still remained over 1.1% due to the declining death rate. If the current birth control policy continues, the Chinese population can be expected to attain a maximum value of 1.4–1.5 billion by the early 21st century before leveling off. Such rapid growth of population has imposed serious burdens on economic growth and energy supply.

ECONOMIC GROWTH

The development of the Chinese economy has followed a tortuous path. In the 1950s, the Chinese Communist Party (CCP) pursued a Marx–Leninist line and followed the former USSR's pattern of socialistic economic development.

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Table 1. *Total population of the People's Republic of China*

Year	Total population (million)	Urban (Percentage by residence)	Rural (Percentage by residence)
1952	574.82	12.46	87.54
1962	672.95	17.33	82.67
1970	829.92	17.38	82.62
1975	924.20	17.34	82.66
1980	987.05	19.39	80.61
1985	1058.51	23.71	76.29
1990	1143.33	26.41	73.59
1995	1207.66	28.22[a]	71.38[a]

[a] 1994 data
Source CSICS (1995).

Heavy industries were given priority at the cost of the living standards of the people, particularly those of the peasants. This class, constituting over 80% of the Chinese population, witnessed a decline in its living standards in this period. This, in turn, led to frustration and the intensification of social conflicts.

In 1958, the late CCP president Mao attempted to solve the problem by thrusting 'Chinese Communism' on the economy and advocating the policies

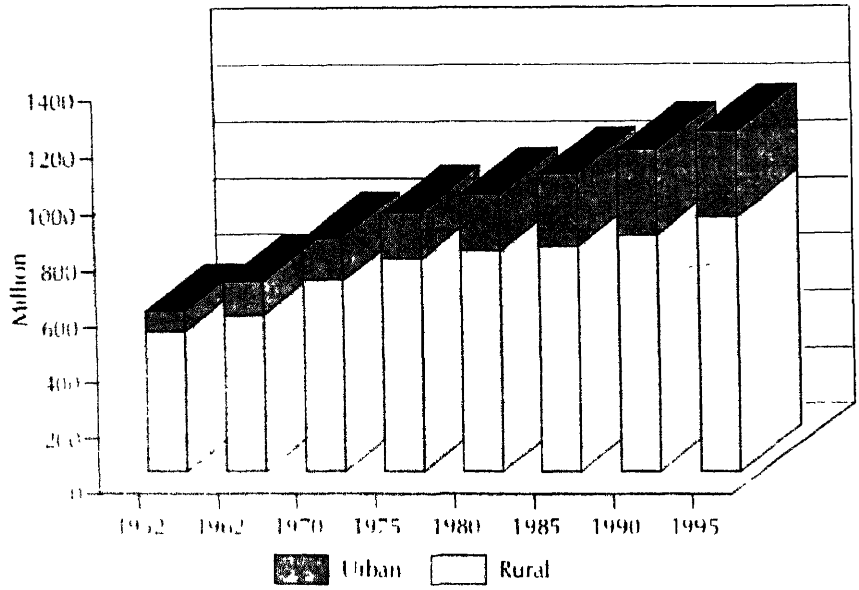

Figure 1. *Chinese population growth*

Table 2. *Rate of growth of the Chinese population*

Year	*Birth rate*	*Death rate*	*Natural (net) growth rate*
1952	37.00	17.00	20.00
1962	37.01	10.02	26.99
1970	33.43	7.60	25.83
1975	23.01	7.32	15.69
1980	18.21	6.34	11.87
1985	21.04	6.78	14.26
1990	21.05	6.67	14.39
1994	17.70	6.49	11.21

Source CSICS (1995)

of the so-called 'Three Red Banners' – the Party's General Line, the Great Leap Forward, and the People's Commune. Such policies seriously violated economical rules, and resulted in unprecedented economic disaster with millions of people perishing in the resulting famine.

In 1966, Mao launched the notorious 'Cultural Revolution' in the hope of regaining control of the country. This led to a political crisis, with the Chinese economy on the verge of bankruptcy.

After Mao's death in 1976, the new CCP leaders tried to change the orthodox political line. Den Xiao-Ping introduced his economic reform policy in 1980, trying to gradually transform the central planning system into a market economy. The new 'Reform and Open' policy actually introduced capitalism into 'Chinese socialism,' and led to the growth of a strange hybrid economy. These new policies have achieved great success in the past 15 years.

In 1980, CCP set up the target of achieving economic growth by quadrupling the gross national product (GNP) in real terms by the year 2000. Several doubts were expressed by experts who considered this target to be very ambitious. However, the development of events proved that this was a correct and powerful policy. The 'ambitious' target has been accomplished years ahead of schedule. By the end of 1995, the Chinese government declared that its GNP, in real terms, had quadrupled from the 1980 value. The current values and the growth rates of the years 1980, 1985, 1990, and 1994 are listed in Table 3. This rapid growth trend is also shown in Figures 2 and 3.

The most important policies that contributed to the success of Chinese economic reforms are listed below.

- *Rural reform 'priority' policy.* The Chinese economic reform began with an active rural reform program, i.e., the abandonment of the effort of the

Table 3. *Chinese GNP growth since 1980*

Variable	*1980*	*1985*	*1990*	*1994*	*1995*[b]
GNP[a]					
Billion RMB	541.78	899.46	1854.47	4491.80	5682.13
Percentage of 1980 value	100.00	166.29	242.67	384.66	423.13
Per capita GNP					
1980 RMB	602.75	766.82	897.03	1227.37	1350.16
Percentage of 1980 value	100.00	127.22	163.75	203.63	224.00

[a] Absolute values in this block are based on current prices; percentages are based on comparable prices; [b] Estimates based on unofficial growth and inflation rates information. The official 1995 value will be available in mid-March 1996

Peoples Commune and the privatization of land under the so-called 'responsibility system'. This policy decisively brought into play the initiative of the peasants, improved the living standards of over 80% of the Chinese population, and guaranteed abundant food supply to the urban region. As a consequence, this policy earned both economical as well as political credits for Chinese economic reforms.

- *An aggressive 'open-door' policy.* This consists of the establishment of 'Economic Special Zones' and many other favorable terms for foreign investors.

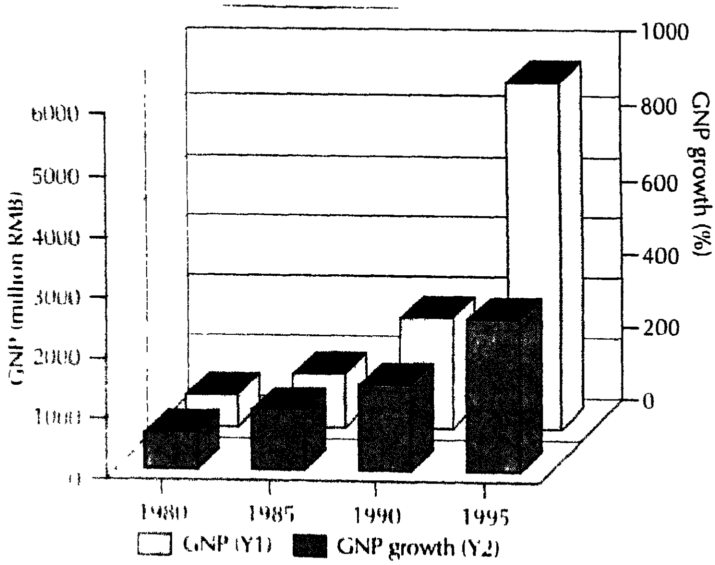

Figure 2. *Chinese GNP growth*

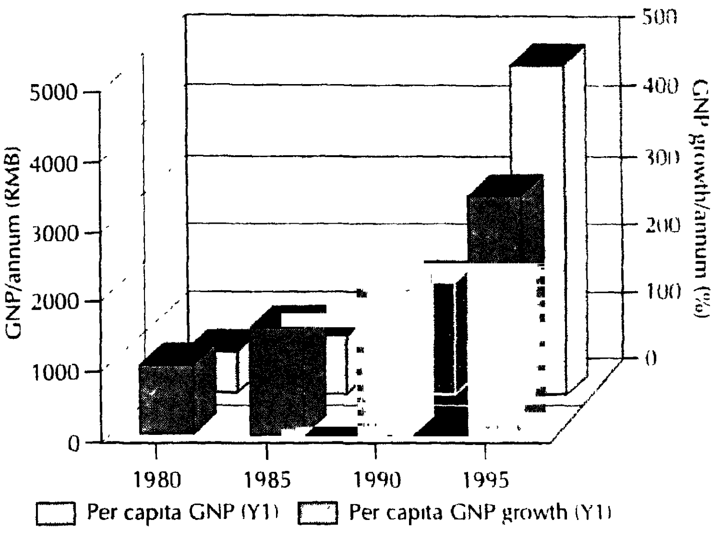

Figure 3. *Per capita GNP growth*

- *Controlled privatization policy.* This policy allows the growth of the private sector inside China, together with the management reforms of the government-owned enterprises.
- *Stringent macroeconomic control policy.* This keeps the inflation rate within acceptable limits.

A number of new problems have emerged in the economic reform process. The most obvious drawback is the resistance of CCP to political reform, resulting in serious corruption and racketeering. The disappointment of the people triggered the uprising of 1989 and the subsequent bloodshed at Tiananmen square. Other drawbacks include the poor performance of the government-owned enterprises, the increasing gap between the rich and the poor regions, and the social conflicts among the new classes. Detailed discussion of these issues is beyond the scope of this paper [see other articles for a better understanding of the root causes and possible solutions, Wu (1990) for example].

ECONOMIC GROWTH AND ENERGY CONSUMPTION AND SUPPLY

BOTTLENECKS FACING CHINESE ECONOMIC GROWTH

As mentioned earlier, many Chinese and foreign experts had doubts regarding the 1980 target of 'quadrupling the GNP by the year 2000'. This target corresponds to an average annual growth rate of 7.2% over a period of two decades. Though this was not considered unattainable *per se*, the primary concern at that time was whether the energy supply would be sufficient to support the ambitious goal. This concern was not unfounded in view of the two energy crises that the world had just suffered and hardly recovered from. Many fast-growing developing countries had, in fact, suffered serious drawbacks as a result of these crises and run into severe debts.

With an enormous population of nearly 1 billion, China consumed 600 million tons of coal equivalent (mtce) of commercial energy in 1980, ranking third in the world in commercial energy consumption. However, per capita energy consumption in China was only 0.6 kgce. This amount was less than five percent of the energy consumption in the US. Such a low level of per capita energy supply could hardly support this ambitious economic goal.

In 1979, the Chinese economy suffered from serious energy/power shortages, and about third of its industrial capacity lay idle. Chinese households could not obtain sufficient fuel for cooking and heating. In the vast rural region, fuel shortage resulted in excessive deforestation and serious desertification. Due to the regulated, very low energy prices, Chinese energy sources, in particular the coal mines, faced bankruptcy. In short, the entire Chinese energy system was in total chaos. Who could believe that a fast-growing economy could take off on a shattered energy supply base?

In addition, the ruling CCP insisted on ideological control and was very reluctant to accept western economic thinking. Even terminologies such as 'cost of money', 'investment return', or even 'elasticity', were considered 'anti-Marxist' and prohibited.

Chinese energy experts, therefore, faced both political and technical challenges while preparing a scientific energy policy for the restructuring of the Chinese energy system.

However, despite all difficulties and uncertainties, a scientific energy policy was initiated in 1981 and successfully implemented thereafter. The development of events, 15 years later, has demonstrated that the fuel needs of 1.2 billion Chinese people have more or less been adequately met, and the ambitious goal of 'quadrupling the GNP' has also been realized.

This paper now discusses, briefly, the successful development and implementation, of the Chinese energy policy. For a detailed description, please refer Lu (1993)

Quadrupling the GNP with Doubling of the Energy Provision

The average energy elasticity of the Chinese economic growth from 1953–1980 was 1.66. If this trend continues over the period 1980–2000, Chinese energy demand would reach 5726 mtce by the year 2000, far more than current world total energy production. Therefore, it will be impossible to meet this demand.

Even if the energy elasticity declined to around 1.0, similar to that in many newly industrialized countries, the commercial energy demand by 2000 will be around 2400 mtce, necessitating the quadrupling of the present energy production. Taking into consideration the tremendous capital investment required, and the long lead time for capability building, quadrupling the energy production within two decades is too ambitious to become a reality.

After carefully analyzing the energy conservation and provision potential, the goal of the Chinese energy policy was aimed at 'quadrupling the GNP with doubling of the energy provision'. This required that the energy elasticity be reduced from the previous average value of 1.66 to about 0.50, requiring massive efforts for energy conservation. Thus, the question arises: was such a target feasible?

The target of doubling the energy supply, i.e., increasing around 600 mtce within two decades, is still a tremendous challenge. The energy industry is a highly capital-intensive enterprise, and a long lead time is very essential. Special measures would, therefore, need to be taken to accelerate the development of new production capacity.

There is yet another complex problem that has not been touched upon. The rural regions rely on noncommercial energy. This has not been accounted for in the above figures. Rural households were facing serious energy shortages. Biomass fuel supply had also been declining due to excessive and continuous deforestation. Large-scale commercial energy supply to the vast rural region was highly unrealistic within a foreseeable future. Innovative solutions had to be found to cope with this critical problem. Chinese energy experts have, in fact, developed and implemented a scientific energy policy that has basically solved all the above seemingly formidable problems, and the outcomes are encouraging. The statistics in Table 4 (see Figure 4) demonstrate the success of achieving the goal of 'quadrupling GNP with doubling of the energy supply' within 15 years instead of the original schedule of 20 years.

INDEPENDENT ENERGY STUDY AND INTEGRAL ENERGY PLANNING

In order to solve such a complex energy problem, Chinese experts carried out an independent energy study and integral energy planning. Based on their bitter ordeals, Chinese energy experts firmly believe that no policy could be effective unless its basis is sound, objective, and scientific.

Extensive energy studies were carried out by the China Energy Research Society, an academic organization without any department or interest bias. As a consequence, objective conclusions were drawn and effective measures were recommended. Comprehensive integral energy planning was then conducted

Table 5. *Chinese energy saving (1981–1987)*

Variable	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*Total*
GDP (10^9 US $)	245.9	257.9	286.0	306.7	348.1	393.9	424.7	464.4	2481.7
Energy consumption (kgce/US $)	602.8	594.5	626.5	660.4	709.0	770.2	880.8	845.0	5014.4
Energy intensity (kgce/US $)	2.451	2.305	2.191	2.153	2.307	1.955	1.904	1.820	2.021
Annual energy saving (mtce)	—	37.6	74.5	91.3	144.2	195.2	232.1	293.2	1068.1

ECONOMIC MEASURES

This approach consisted of the use of incentives and economic measures, including the gradual deregulation of energy prices and the provision of energy conservation investments, loans, and subsidies. Table 5 shows the statistics of the energy savings achieved from 1981–1987. It is noteworthy that a total energy saving of over 1 billion tce has been achieved. Taking into consideration the cumulative effect of this achievement, the success of the Chinese comprehensive energy conservation policy is obvious.

THE FAST GROWTH RATE OF ENERGY PRODUCTION: WALKING ON TWO LEGS

In view of the tremendous scale and the complex nature of the Chinese energy problem, the key to Integral Energy Planning is 'to walk on two legs'. This policy emphasizes energy conservation and energy provision; commercial and traditional energy; conventional and new commercial energy; demand- and supply-end management; domestic and foreign involvements; and hard- and soft-science approaches.

In order to double the provision of commercial energy within two decades (actually accomplished in 15 years), the 'walking on two legs' policy is most effective The domestic primary energy production reached 1187 mtce, or 186% of the production in 1980. The growth of total primary energy production is shown in Table 6 (see Figure 5).

The share of coal increased steadily while that of oil decreased. The share of hydro power also increased; however, its share is small when compared to that of coal and oil. The rapid increase of coal production relied heavily on the 'two legs' policy. The share of coal production from the state-owned coal mines decreased from 56.48% in 1980 to 44.29% in 1988. 75% of the incre-

Table 6. *Domestic primary energy production of China*

Year	Total energy production (mtce)	Share of various products (percentage of total)			
		Coal	Oil	Gas	Hydro
1980	637.35	69.4	23.8	3.0	3.8
1985	855.46	72.8	20.9	2.0	4.3
1990	1039.22	74.2	19.0	2.0	4.8
1994	1187.29	74.6	17.6	2.0	5.8

ment of 360 in coal supply, from 1980 to 1988, was met by locally-owned small coal mines.

Another example of the 'two legs' policy is provided by the power sector. The growth rate of the power sector was higher than that of the total energy sector, basically matching the growth rate of the economy. Formerly, all the investment in the power sector came from the state budget. It was, therefore, impossible to triple this budget to meet the requirements of the construction of a power plant. The only solution was to rely on another 'leg', that is, to raise capital from other sources. This policy was implemented very effectively.

In 1980, the state provided nearly 99% of the total capital for the power sector. But, in 1988, the total investment increased to 600%, of which 60% was provided by other sources.

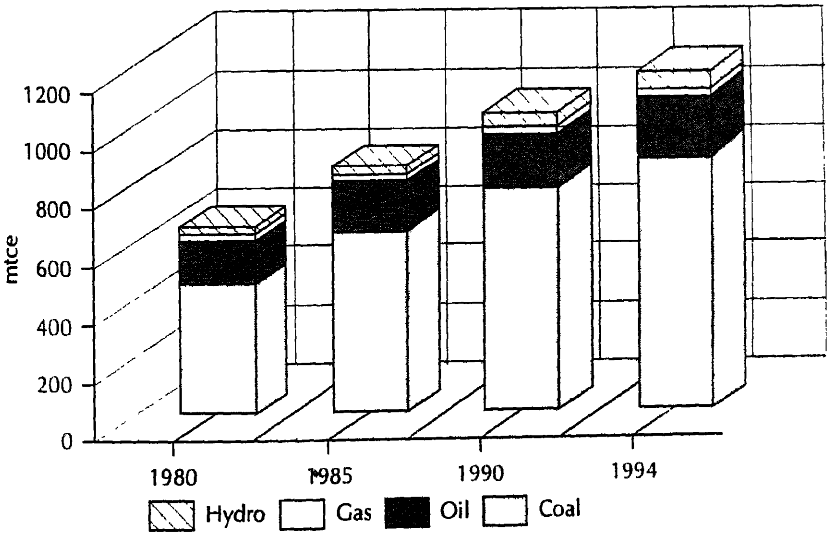

Figure 5. *Chinese energy production growth*

THE COMPREHENSIVE RURAL ENERGY PROGRAM

China has successfully solved at least the basic rural energy problem by implementing a comprehensive rural energy program. A very detailed investigation of the Chinese rural energy sources and energy situation was conducted, and integral planning at the national, provincial, county (typical), and village (typical) levels was carried out. The rural energy programs were implemented at the local level, but were closely monitored and assisted by the central and provincial governments. The general rural energy policy was to ensure that rural energy supply was 'in line with local conditions, supplementing various energies mutually, utilizing resources comprehensively, and emphasizing economic benefits'. This policy has been implemented with great success. Some major elements and achievements of this program are discussed below.

DEVELOPMENT AND DISSEMINATION OF FUEL-SAVING STOVES

The most successful rural energy program in China, and perhaps the world, is the development and dissemination of over 100 million fuel-saving stoves in the past decade. An overview of the fuel stove program is shown in Table 7 (see Figure 6). This achievement is particularly impressive because it has been accomplished in such a vast country with one billion people residing in varying geographic and cultural conditions. This experience has attracted the attention of the international energy community and has been widely discussed all over the world. Many articles have described the detailed experience of this program. The success of the program is attributed to precise policies and an appropriate approach.

INCREASE OF FIREWOOD SUPPLY BY AFFORESTATION

A campaign for afforestation began in 1980. The new policy advocating the private ownership of small woodlots and trees around houses was enthusiastically received by the peasants. About 6 million hectares of firewood were

Table 7. *Chinese national and provincial fuel-saving stove programs (million households)*

Programs	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*Total*
National pilot counties	90.0	200.0	100.0	97.0	101.0	96.0	51.0	735.0
National programs (millions)	2.6	11.0	8.4	9.9	8.9	10.0	9.9	60.7
Provincial programs (millions)	4.0	9.7	9.5	8.5	9.1	7.5	5.0	53.3
Total households (millions)	6.6	20.7	17.9	18.4	18.0	17.5	14.9	114.0[a]

[a] By the end of 1990 the total number increased to 120 million, and by early 1992, 129 million
Source: Smith (1993)

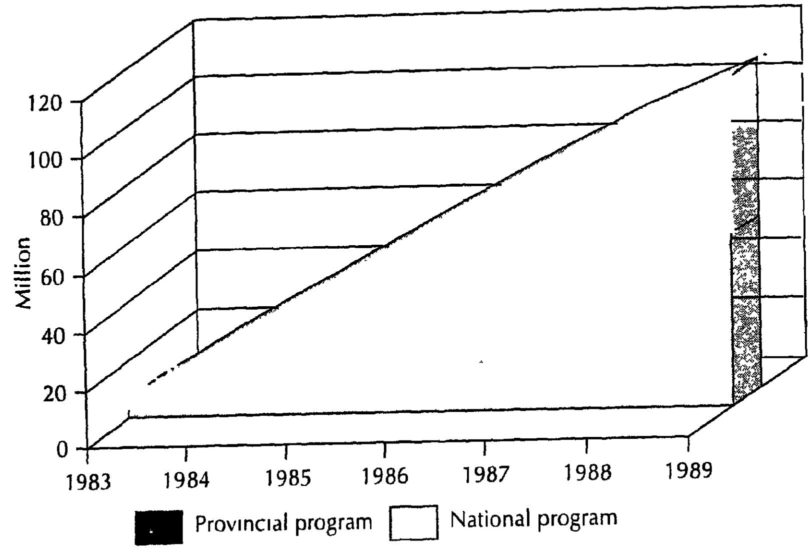

Figure 6. *Chinese fuel-saving stoves growth*

planted under the Sixth Five Year Plan, corresponding to about one-fifth of the previous barren hills and slopes available for afforestation. More afforestation campaigns have been implemented in the following five year plans as well.

MINI HYDRO POWER AND RURAL ELECTRIFICATION

One principle that the Chinese rural energy policy followed was to utilize local energy sources as far as possible. In many mountainous regions with ample annual rainfall, mini hydro power is considered a natural endowment for rural energy. China has developed cheap and reliable equipment for mini hydro power generation. In 1989, mini hydro power stations in the Chinese countryside numbered 50 862 with a total capacity of 4168 GWe, and supplied about 13% of the total rural electricity.

China has launched a rural electrification program that follows a three-stage approach. In the preliminary stage, 90% of all the households in a given county will have electricity and the annual per capita power consumption will reach 200 kWh. In the second stage, 95% of the total households in a given county will have electricity and the annual per capita consumption will reach 400 kWh. The final stage would be the comprehensive electrification of all the households in a given county. 100 counties have been selected for the first stage of the demonstration program, and most of them achieved the goal in 1990, illustrating the success of the program.

BIOGAS PROGRAM

The Chinese biogas program has experienced many ups and downs, and is not considered as successful as the other rural energy programs. Only 7.5 million biogas digesters were built in 1990, as compared with 120 million fuel-saving stoves. The major reasons are the complexity of the biotechnical process and the limitations of the climate and the feedstock. However, the biogas program is regarded as a comprehensive energy sanitation program in rural regions, and will continue on a moderate scale.

CONCLUSION

The success of the Chinese energy policy in fueling 1.2 billion people and quadrupling the GNP within 15 years has demonstrated the power of truly scientific policies and their effective implementation. The development and implementation of such a policy requires adequate political and social climate. However, tremendous efforts and sacrifices have been made. Based on their own experience, the energy community in China firmly believes in a Chinese proverb

> *Although the road to success is tortuous, the future of mankind is always bright.*

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THE TEHRI DAM PROJECT AND ISSUES OF POPULATION, DEVELOPMENT, AND ENVIRONMENT

Ashish Bose[1]

GENESIS

The continuing controversy over the Tehri Dam Hydro Power project in the Western Himalaya for the last two decades, and recent events, like the stalling of the project after the 49-day hunger strike was called off by the environmentalist, Sunderlal Bahuguna, in light of the Prime Minister's assurance to review the project, qualify the Tehri Dam Project as a worthy case study. The Tehri Dam project has important lessons for engineers and environmentalists, not only in India, but throughout the world. Planners and policy makers can be cautioned about the hazards of going ahead with technology while disregarding sociocultural factors. The total reliance on engineering aspects has made this project an example of arrogant technology combined with sociocultural insensitivity.

A power engineer is not the best person to appreciate the deep reverence for rivers in India, nor is a worshipper of the river Bhagirathi, which, mythology says, has its source in the matted hair of Lord Shiva and culminates in the holy Ganges (Ganga), the best person to appreciate scientific data on dams. But the power engineer is perhaps the best person to accept the assertion of engineers that the Tehri Dam has been designed to withstand a maximum earthquake of the magnitude of 7.0 on the Richter scale, with an epicenter of 27 km from the dam site. The engineer goes by 'scientific' data, while the worshipper of the sacred river quotes scriptures and mythology. In comes the environmentalist who respects both science and nature, and we then face the world of 'environmental impact' reports. Then comes the social activist who speaks up for those people who are rarely consulted in matters of ongoing developmental projects. Big dams require big money. It is then that the World

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Bank and other donor agencies, including foreign experts of all hues make their entry. The World Bank and the other donors are not expected to conduct a direct dialogue with the people. For that we have the bureaucrat accompanied by his masters – the politicians, in particular, the concerned ministers (for irrigation/power/environment) and even the Prime Minister. The drama gets more and more intricate. The media gets into the bandwagon. This generates a lot of emotional literature and the controversy flares up further. 'Fast unto death' to save the sacred rivers becomes a legitimate Gandhian method of resistance. The Government responds by agreeing to appoint one more review committee. There is temporary peace, which often means a lull before the storm.

This case study is based on field work conducted at the project site and includes discussions with the people there as well as with a wide range of people in New Delhi. Various published and unpublished works on this project have been referred to and views from firsthand discussions with Mr Sunderlal Bahuguna, an environmentalist and social activist of international fame, who has been relentlessly opposing the Tehri Dam Project for about two decades, are also incorporated.

As a demographer interested in policy research (Bose 1994; 1996) the subject of distress migration is of particular interest to me, and within this theme, more specifically, the issue of migration of 'oustees' or people whose land and houses would be submerged when the dam comes up. The entire town of Tehri would get wiped out. This led me to take up a study on the fate of more than 20 000 people in this old town (apart from thousands of oustees from adjoining villages which would also be submerged). I did see the new township which had been built – New Tehri – but it was a sad example of poor town planning, and betrayed a lack of understanding of the issues of population, environment, and development. The only impressive aspect of New Tehri was, perhaps, the spacious jail with a magnificent view of the surrounding hills, i.e., if one is not chained in the prison rooms!

HISTORICAL BACKGROUND

Soon after independence, in order to augment the supply of water for irrigation and agricultural development and the supply of electricity for fostering industrialization, the Government considered the possibility of hydro power generation, particularly the construction of dams. The Bhakra-Nangal Dam became a reality in the course of time and has played a large role in the green revolution in Punjab, Haryana, and Western Uttar Pradesh. A large dam was then contemplated in the Tehri Garhwal region of the Western Himalaya in Uttar Pradesh. In 1972, the Tehri Dam project was officially approved (see Annexure I for details of location). A 260.5 m rock-filled dam was to be built below the confluence of the Bhagirathi and the Bhilangana rivers in order to generate 600 MW of electricity. Later, the plan was revised and the installed capacity was raised to 2400 MW. Administrative clearance was given in 1976. Soon after, the agitation against the dam started, led bv Sunderlal Bahuguna. The agitation is still on and the project has been in hibernation for the last 20 years. Several committees were appointed to look into the different aspects of the dam (for an elucidation of the viewpoint of opponents of the dam, see Annexure III).

Of particular relevance in our discussion is the report on the *Environmental Appraisal of the Multi-purpose Tehri Dam Project* (1990), prepared by a technical committee under the Chairmanship of Dr D R Bhumbla, a noted agricultural scientist (Annexure II). The Committee concluded

> *Taking into consideration the geological and seismic setting, the risks and hazards, ecological and social impacts accompanying the project, the costs and benefits expected, and after a careful examination of the information and data available, the Committee has come to the unanimous conclusion that the Tehri Dam Project, as proposed, should not be taken up as it does not merit environmental clearance* (Bhumbla 1990: 10).

Earlier, the Indira Gandhi Government set up another Working Group under the Chairmanship of Mr S K Roy, an environmental expert. A draft report was prepared but it was alleged that adequate data were not collected and that the Government tried to suppress the inconvenient views of some experts. Mr Roy rejected the report in 1986 and opposed the dam on account of the 'known instability of the hillsides, the extensive deforestation, and the location of the Tehri dam in a highlv sensitive seismic zone' (Kutty 1994: 126). In 1987, the Tehri Dam project was selected for Indo-Soviet cooperation 'involving technical and financial assistance from the Soviet Union'. To overcome fears about the destruction of the dam by an earthquake, it was pointed out that the Soviet experience of dam construction – the Nurek dam and the Roqu dam in Central Asia's seismic zone – would ensure the safety of the Tehri Dam.

Kutty observes that the decision regarding the Tehri dam was taken 'in the name of diplomatic exigency'. He continues

> *Tehri dam had a hoary history. Civil engineers and contractors had painted verdant pictures of sprawling fields which could be watered when the dam was built. Projections of farm production were striking. The effort was to create a colorful illusion of development by employing the magic of statistics. The gains of Tehri seemed overwhelming when presented through the poetry of civil engineering and the politics of works contract* (Kutty 1994: 125).

Kutty also records that

> *...like Soviet aid was available for Tehri, America had promised 600 million dollars for the Bodhghat project in Bastar in Madhya Pradesh.*

In 1993, the Government of India had appointed a committee for reviewing the Bodhghat hydroelectric project in Bastar district, headed by Mr M N Buch, an outstanding administrator and environmentalist. The Committee concluded

> *The Bodhghat project is' ill-conceived in that for a minor quantity of power a very diverse, dense, and rich forest will be permanently destroyed. Ecologically, the project would be a disaster, because in its conceptualization it has fully ignored environmental importance of water, vegetation, and forest fauna, while at the same time completely overlooking a vital element of the ecosystem – man. The entire riverain system of the Indravati River will be disturbed and the forests of Central Bastar brought under considerable threat and human habitation ruined. Under these circumstances, the Committee strongly recommends that:*
>
> 1. *environmental clearance be refused to the Bodhghat project and any earlier clearance be cancelled;*
> 2. *suitable directions be issued to the Madhya Pradesh government to take necessary steps to protect the forests of Bodhghat, in particular, and Central Bastar, in general. This would include the carrying out of silvicultural operations in the pine plantation area, which is now showing signs of reverting to the original forest;*
> 3. *a very serious view be taken of the proposed projects at Kulru, Nugur, and Bhopalpatnam, especially in light of the observations of the committee on the Indravati river, as a whole; and*
> 4. *the chapter of the Bodhghat project be firmly and finally closed* (Buch 1993: 18).

BIG DAMS VERSUS SMALL DAMS

K S Valdiya, an eminent geologist, currently at the Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, opposes big dams and, in particular, the Tehri Dam project. To quote him at length

> *Recognizing the great need for storage of water in the Himalayan rivers for irrigation and power generation, and considering the serious envi-*

> *ronmental and sociocultural problems which the building of big dams create, it is better to go in for many small dams – 10 to 30 meters high with reservoir capacity of 50 000 to 1 lakh cubic meters and electricity generation of 5000 kW. Small dams not only cost less, start giving benefits quite early, but also bring greater benefits and cause less damage or impairment of environment, croplands and human habitats.*
>
> *The analysis of the Planning Commission figures...demonstrates that it costs over Rs 2800 to provide irrigation to one hectare of land through major/medium irrigation schemes compared to just Rs 840 for an equal area by groundwater schemes. It is, however, true that the cost of production of electricity is high for small hydel schemes – Rs 15 000 to 8000 per kW compared to Rs 7000 to 3000 per kW by large hydel projects...However, if one thinks of the real (total) cost of water resource development projects which also includes the environmental and resource losses, the cost of damaged land and the enormous expenditure on the relocation of uprooted communities of people, this high cost of electricity by small hydel schemes is more than compensated* (Valdiva 1995: 42).

With his article on 'Mounting antagonism towards big dams' (Dhawan 1989), B D Dhawan, an irrigation economist, initiated a nationwide debate on big dams. A series of papers published on this subject by different authors was brought together in a book edited by him (see Dhawan 1990). He examines various aspects of the cost of major and minor irrigation works and concludes that

> *...the case for according priority to minor irrigation development in India's water planning on grounds of cost economy is not well founded in facts* (Dhawan 1990: 125).

However, Ashok Mitra, an economist, criticizes Dhawan's methodology and maintains that

> *...the rent-seeking elements (i.e., kickbacks and fictitious expenditure) which are to be excluded from total cost would be peanuts before the real resource cost in terms of land submerged and the loss of forest by major irrigation works, and to this if we add real resource cost of rehabilitation of the displaced households, the real resource cost would appear to be phenomenal* (Dhawan 1990: 142).

In reply, Dhawan writes

> *To what extent future empirical investigations will falsify my assertion in favor of major irrigation is yet to be seen. Even if these are proved false, no serious policy changes in water planning would arise* (Dhawan 1990: 148).

Kanchan Chopra, an economist, in her contribution in Dhawan (1990) on 'Large dams and cost-benefit analysis' is more theoretical in her approach. Of particular relevance to us is the discussion on the Tehri Dam based on a series of technical reports prepared by the Tehri Dam Project Authority (1969; 1983; 1986) and V Paranjapye's (1988) study..

Kanchan Chopra takes a critical view of both the official reports on the Tehri Dam, as well as Paranjapye's analysis. She calculates the benefit–cost ratio using the United Nations Industrial Development Organization (UNIDO) methodology and concludes that

> *...the project continues to be not viable even after the UNIDO methodology has been followed* (Dhawan 1990: 189).

REVERENCE FOR SACRED RIVERS

It would be manifestly wrong to confine the discussion on the Tehri Dam to benefit–cost ratios worked out by economists, no matter how much concern the economists show for social cost. The sociocultural aspect cannot be relegated to the back seat. The Indian reverence for rivers and mountains can no more be treated as superstitions. In any people-centered development program, the perceptions of the people assume paramount importance. Unfortunately, there is no sociocultural study of the Tehri Dam Project. Baviskar (1995: v), in her sociological study of the Narmada Valley Project, starts with a quotation from Kashinath Trivedi

> *It is the dharma (duty) of a river to keep flowing.*

During our field work in the villages affected by the Tehri Dam, we were constantly reminded of the free flow of water in the Bhagirathi leading to the Ganges, the most sacred of all rivers. Madan Mohan Malviya, a great nationalist, had organized a powerful movement between 1914–1916, when there was a proposal to divert the water of the Ganga to a canal. On his deathbed Malviya sought a promise from Justice Shiv Nath Katju

> *...promise that you will raise your voice against any plan to obstruct the free flow of the Ganga.*

Bahuguna quotes a contemporary revolutionary from Bengal (Pannalal Babu)

> *Ganga is not a river. She is our life. Tampering with the Ganga is piercing our heart* (Bahuguna 1996).

Thus the whole controversy about the Tehri Dam Project must be viewed in the wider context of culture and religion, which is woven into ecology and the environment.

A major cause of opposition to the Tehri Project is the fear of earthquakes. The earthquake in the neighboring district of Uttarkashi in 1990 shattered the confidence of the common man in engineers who have assured that the Tehri Dam would be earthquake-proof. Much of the technical confidence in engineering skills is dubbed as the arrogance of technology. The people of that region put more faith in God than in engineers. It is contended that an earthquake or the bursting of the dam would completely devastate the holy cities of Rishikesh and Haridwar. What is at stake, therefore, is the foundation of religion and it is not merely a matter of irrigation or electricity. Nobody denies the great need for augmenting the supply of water and electricity but is building big dams the only way to generate electricity or develop irrigation? Are irrigation and power engineers the only persons whose verdict should be final? Is life governed by benefit–cost ratios? Whose cost and whose benefit?

In a field study on the reconstruction of life by the oustees of the big Hirakud dam Project in Orissa, Balgovind Baboo, a social anthropologist, concludes

> *The mad rush for multi-purpose dams like the Hirakud dam must be stopped at the earliest. The forces of Nature must be curbed as little as possible so that man becomes its friend and not its foe* (Baboo 1991: 140).

The study also reveals that

> . *the dam has failed in its major objectives like electricity, irrigation, flood control and enhanced agricultural production* (Baboo 1991: 149)

LACK OF ADEQUATE STUDIES AND DATA

In a detailed discussion, B K Roy Burman, a member of the Bhumbla Committee on Environmental Appraisal of the Tehri Dam Project, expressed his indignation at the fact that the Project authorities tried to mislead the Committee by taking them round some 'showpiece' villages where the dam oustees were resettled; but when the Committee members paid unscheduled visits to some other villagers, they received a bleak picture of resettlement from the oustees. Mr Burman, who is fully conversant with the developments of the project, feels that in the absence of adequate data, it is not possible to take a stand on the controversial dam issue. He endorses the Bhumbla Committee report, according to which

> *...no study has been done on the ecological impact of all these projects on the river, on its water quality, its flora and fauna, and its ability to survive as an ecosystem* (Bhumbla 1990: 7).

Our quick field study in the Tehri Project area reveals a mixed picture of the oustees. For example, there are several families in the old Tehri town who have already collected their monetary compensation and received land in exchange for their property which would be submerged. However, as the Tehri town is still intact, they have gained rather than lost in the process. Our local investigator reported that there were several cases of corruption on the part of members of joint families, who claimed the entire house as their individual property and, in the process, multiple compensation was paid for the same property. There were also frequent complaints against the officials of the project, who were accused of widespread corruption.

Perhaps the most balanced contribution in the literature on the Tehri dam is that of Bandhopadhyay (1995). Elaborating on the policy implications of a big dam like Tehri, not only for India, but for other countries as well, he comments

> *The progress of the debate on the Tehri Dam will definitely act as a guideline for future decision making in the case of other big dams proposed in the Himalaya. For countries like Nepal and Bhutan, water resource is the most important natural resource from the viewpoint of economics. The focusing of the debate on the seismic risks may extend the debate to a new dimension of upstream–downstream conflict in the region. When both the upstream and downstream areas of the dam fall within one northern state, as in the case of Tehri, the decision making process is often influenced more by the economic growth factors at the cost of social and environmental damage factors. However, when the upstream and the downstream areas fall in two different countries, as will be the case for dams all along the southern border of Nepal and Bhutan, this will not be the case. Under this situation, the question of dam safety will then be addressed singularly by the downstream country and governed by international law. This will create an additional factor for the downstream country to influence decisions in the upstream country. Since all the future water management projects will have to depend on the question of storage, the present uncertainties related to the seismic risk from large dams in the Himalaya need to be addressed at the earliest. Otherwise there is a strong possibility that dam issues may become subject of international litigation* (Bandhopadhyay 1995).

CONCLUSION

On the basis of the field work in the area of the Tehri Dam, our interaction with the authorities, engineers, environmentalists and, more importantly, the common people, as well as on the basis of the study of literature on the subject, the situation can be summed up as follows.

Soon after Independence, significant importance was given to the harnessing of big rivers through dams in order to provide increasing irrigation for agriculture, and electricity for industrial development. Dr K L Rao, a technocrat minister, put forward an ambitious plan of linking rivers and developing river valley projects. In those days, neither India nor the world was environment-conscious. The idea of constructing a dam in the Western Himalayan region (Tehri Dam) was put out in good faith. Likewise, the involvement of Soviet expertise in building big dams in seismic zones was also done in good faith Similarly, the resistance to the dam by environmentalists like Sunderlal Bahuguna was motivated by genuine ecological concern and the welfare of the poor people in the hills. In the face of controversy, the Government of India appointed committee after committee to examine the pertinent issues. There is no evidence to suggest that the members of the various committees were not objective in their assessment. Finally, the innocent people of the hills cannot be faulted for their genuine apprehension about a possible earthquake and a dam burst wiping out the priceless cultural heritage of India, reflected in the sacred towns of Haridwar and Rishikesh. Then why this impasse about the Tehri Dam project?

In our view, the decisions regarding the project should take note of the following imperatives. There should be no room for arrogance of technology. Sociocultural factors are equally important and cannot be written off as superstition Reverence for rivers and mountains is sound ecology and good economics It is generally accepted that in any benefit–cost analysis, social costs should also be adequately noted, but what about *cultural* costs? Can one write off the pervading impact of religion on the daily lives of the people? The oustees in the Tehri Dam Project Area will have to be offered an acceptable, realistic, and viable rehabilitation plan for their resettlement in new areas. India has enough expertise to tackle engineering problems in regard to the height of the dam, earthquake-proof technology, and related technical issues. There is very little need for foreign experts or even foreign funding for such a project The Himalaya must be saved, the forest must be preserved, and human beings must live in harmony with nature. These are not platitudes, but imperatives for the 21st century At the same time, one should not take a romantic view of the environment and oppose all developmental projects.

Development must be centered around the people. In a democracy, the development process must be participatory in nature. Furthermore, in the name of science and technology, development should not become culturally insensitive.

When one takes up projects like the Tehri Dam in a seismic zone, there should be detailed planning for disaster management – natural disasters as well as man-made disasters.

This paper is not simply a case study on a big dam project. It has wider national and international implications for donors, planners, and policy makers. In spite of several committees being appointed from time to time, a scientific body of information on the complex issues involved have not been developed in a systematic way. It would be manifestly wrong to confine such data only to the engineering aspects of the generation of energy. The people must have priority and, therefore, data on social science are vital. Technology and social transformation must progress hand in hand in order to improve the quality of life of the common people.

ANNEXURE I

THE PROJECT AREA

Situation

The Tehri dam catchment project area (Table 1) lies in the Garhwal hills of the Central Himalaya in Uttarkashi and Tehri districts of Uttar Pradesh. It extends from 30°15'30" N to 31°15'N latitude and from 78°0'0" E longitude. It covers the catchment areas of the rivers Bhagirathi and Bhilangana. The area of the project is 6921.25 km^2, roughly 0.56% of the total area of Tehri and Uttarkashi districts. More than 25% of the area remains covered by snow.

Table 1. *Tehri project area*

Districts	*Total geographical area (km^2)*	*Area under the Project (km^2)*
Uttarkashi	8016	5229 87
Tehri	4421	1791 38
Total	12437	6921 25

Note The project area is bound by various subwatersheds North Himachal Pradesh and China, East Sanswat, Mandakini, and Guptakashi, South South Bhagirathi, Badiyargad, and Dangchaoura, and West the Yamuna catchment
Source THDC (1990)

ANNEXURE II

EXCERPTS FROM THE BHUMBLA COMMITTEE ON THE *ENVIRONMENTAL APPRAISAL OF THE TEHRI DAM PROJECT* (15 FEBRUARY 1990)

Environmental Assessment of the Tehri Dam Project

From a study of the Tehri Dam Project, it became clear to the Committee that the decision on its environmental viability and optimality would depend on the following factors.

1. The ability of the dam structure, as designed, to withstand the maximum credible earthquake that can be expected in the region during the anticipated life of the project.
2. The ability of the hillsides and reservoir rime in the project area to withstand such an earthquake.
3. The implications of dam failure on life and property downstream.
4. The rehabilitation package being offered to the oustees, in terms of what is proposed and how well it has been implemented so far.
5. The ecological damage that the project would cause, and the planning and implementation of preventive and mitigative measures.
6. The costs and benefits of the project, especially in terms of adequate financial provisions for all the issues listed above, and keeping in mind the need to ensure that the benefits anticipated are realizable. It must also be ensured that the benefits go to the deserving sections of the society, especially to those regions and individuals who are being negatively affected by the project, and justify the nonquantifiable social and ecological costs that all such projects inevitably have.

Comments on the Findings and Recommendations of the Committee

A Seismic Design of the Dam

The project authorities and experts from the Central Water Commission assured the Committee that the dam has been designed to withstand a maximum earthquake of the magnitude of 7.0 on the Richter scale, with the epicenter 27 km from the dam site However, the Committee did not examine this assertion in any great detail, for it considers the magnitude of the earthquake, taken as the maximum credible one, to be inadequate.

The Committee is of the opinion that the maximum credible earthquake for which the dam should be designed is M > 8.5 on the Richter scale, 27 km from the dam site This conclusion was based on discussions with various experts, including Dr V K Gaur, Secretary, Department of Ocean Development, Government of India, and Dr Harsh Gupta, Vice Chancellor, Cochin University. The facts and arguments offered by these experts make the Committee believe that there is almost a certainty that during the anticipated life of the project an earthquake of the magnitude of 8.0 and above could occur in the region. Although the Committee is aware of the differing viewpoints on this question, it is convinced that, given the facts, the experience and stature of the experts consulted, and the horrific implications of a dam failure, it would be irresponsible to clear the Tehri Dam, as it is proposed currently.

Stability of the Rim and Hillsides

The reservoir rim and hillsides have been tested, if at all, for an inadequate seismic level. This is especially important because, if the hillsides collapse due to an earthquake, the implications would be equivalent to that of the collapse of the dam.

Implications of Dam Failure

Though no risk analysis had been carried out by the project authorities, the Committee's calculations, albeit preliminary, showed that if the dam collapsed, or was overtopped due to a collapse of the hillsides, the resultant water wave would wipe out Rishikesh and, possibly, Haridwar. The loss to life and property is incalculable, but imaginable.

These observations reassert the fact that it would be very irresponsible to construct a dam which is anything but safe. It also highlights the necessity to prepare a detailed Disaster Management Plan, based on risk assessment, something that has not been done yet.

Rehabilitation

The Committee noted that the rehabilitation package being proposed for the Tehri Project is inadequate, and much inferior to that accepted for other similar projects, like Sardar Sarovar in Gujarat. It was also noted that the planning and execution of the rehabilitation program was very poor. The estimate of the total number of people likely to be affected was in dispute, land to rehabilitate affected people had still not been acquired, and the legal title for the land had not been transferred to even those shifted 10 years back. Most of the land given to the oustees is sandy, stony, and of low productivity. The condition of those relocated 10 years back was appalling and did not augur well for those to be rehabilitated in the future.

It is well recognized that unless planning, identification of land, and provision of sufficient resources for rehabilitation is carried out prior to the clearing of the project, it becomes very difficult to ensure justice for the people ousted due to the project.

The Committee is, therefore, convinced that the rehabilitation package should be improved, adequate and appropriate land identified, and sufficient provisions be made for rehabilitation in the Project budget, before the project can be considered.

Ecological Damage

The damming of any river has significant ecological impacts. The damming of a hill river, especially the Bhagirathi, which already has three existing and proposed run-of-the-river projects, has even greater than normal ecological impacts. Unfortunately, no study has been done on the ecological impact of all these projects on the river, on its water quality, its flora and fauna, and its ability to survive as an ecosystem. Considering that the impact of ecological degradation of this riverain ecology will not only affect the local area, but will also have an accumulative impact on the Ganga, there is an even greater urgency to study this and prevent the occurrence of such an event. The Committee also felt that the project did not merit environmental clearance in the absence of adequate studies and action plans.

Cost-benefit Analysis

Apart from the cost implications of the various recommendations made above, there are several unresolved issues which require mention.

Catchment Area Treatment

Only 15% of the degraded catchment has been proposed for treatment. Considering the implications of the state of the catchment on the life and the safety of the dam, and the unstable state of the catchment of Tehri Dam, the entire degraded portion of the catchment needs treatment, with a much higher financial outlay than that presently proposed.

Siltation Rates

The current measurements of suspended and bed-load silt are not satisfactory. The committee anticipates that the actual rates of siltation would, perhaps, be higher, and differ from current calculations. This has implications on the life of the Dam, and the resultant cost–benefit ratio.

Bhagirathi Development Authority

In conformity with the objective of achieving sustainable development in the Bhagirathi Basin, the Committee reiterates the recommendation that a *Basin*

Management Authority must be set up so that professional inputs are available to devise and implement a project portfolio, within the carrying capacity of the basin, for its integrated development, and to maximize the flow of benefits to the local people. The Committee was informed that the formulation of such an authority had been mooted by the Ministry in early 1987 but it has not materialized yet. The highest priority should be given to the setting up of a *Basin Management Authority*, that deals not just with water resources but also looks after the integrated development of this basin. The cost implications of such a setup should also be worked out.

Command Area Development

Despite repeated requests, the committee was not provided details regarding release of water from the Koteshwar dam for utilization in the command area, even though it is claimed that irrigation requirements would be governing such releases. In the absence of these details, it is not clear whether the releases would be governed by the requirement of power generation, irrigation, or both.

An area of 2.7 lakh hectares is proposed to be irrigated in the existing command of the Upper, Madhya, and Lower Ganga canal systems. In view of the substantial rainfall supplemented by surface and ground irrigation in the Upper and Madhya Ganga canal commands, the extent of additional irrigation required has not been established. Additional water released in this command is likely to create problems of water logging and salinity if extensive drainage facilities are not carefully planned and executed. However, no such details are available.

A representative of the Central Water Commission informed the Committee that a report on the utilization of the Tehri water in the Command area is still under consideration. Until such a plan has been finalized and assessed, it is not possible to assess the impact of the project on the command and, therefore, its benefits and viability.

For these reasons, the Committee feels convinced that the economic viability of the Project needs to be reexamined, and that the present cost–benefit analysis is not adequate.

Conclusion

Taking into consideration the geological and seismic setting, the risks and hazards, the ecological and social impacts accompanying the projects, the costs and benefits expected, and a careful examination of the information and data available, the Committee has come to the unanimous conclusion that the Tehri Dam Project, as proposed, should not be taken up as it does not merit environmental clearance.

ANNEXURE III

EXCERPTS FROM THE MEMO PRESENTED TO THE PRIME MINISTER BY SUNDERLAL BAHUGUNA ON 7 MAY 1992

Review of the Tehri Dam Project

Until now, the stress has been only on the technical issues – whether the dam can withstand an earthquake of 8.5 magnitude on the Richter scale. It is said that the design has been revised thoroughly and that the dam will be safe. It is doubtful whether a dam which was designed for an earthquake of 7.2 on the Richter scale (according to evidence presented by Mr Docodov, the leader of the Russian geologists, before the Bhumla Committee) can withstand an earthquake of higher magnitudes. The Russian structures are often mentioned to support this, but it should be examined within the context of the structures mentioned in the USSR report and the geological conditions of hills there. In this context, it should be seen how the revised design has been fitted into the base of the dam, which was fixed as early as 1978, when the work on the diversion tunnel started.

So far as the impact of the Uttarkashi earthquake is concerned, it should not be seen in the narrow sense of what happened at the dam site, because the epicenter of the earthquake was near the Maneri Dam which is more than 80 km from Tehri. The propaganda carried on by the dam builders that there has been no damage to the dam is ridiculous because no dam exists as yet. However, the dam site is so fragile that there are wide cracks at least on the right bank slope between the top terrace and the diversion tunnel head. These cracks were often filled but when, during the 76 day *dharna* (strike), the dam builders could not enter the site to hide this, the crevice widened. These spots would be visible to anybody who cares to enquire.

Even if it is assumed that the structure of the dam is strong, the surrounding hills which are fragile cannot be prevented from falling down into the reservoir. This had happened in the case of the Vijont dam in Italy in 1963.

Another aspect of this problem is the creation of several cracks which have developed in the earthquake-hit zone of the Bhagirathi catchment, especially above the Pata and Sangrali villages near Uttarkashi, the Saur and Thandi Kamad villages of the Jalkur valley, and the Maid-Marawaari, Newalgaon, and Bhatgaon villages of the Balganga valley. These areas have attracted attention because of their proximity to habitats. But, the area of the Bhagirathi catchment, which is more than 7000 km^2, is not located close to any habitat. There is a need to make a detailed on-the-spot study of the higher ridges where such cracks are feared. The past history of big landslides in this catchment right from Gomuckh glacier bears the evidence of huge landslide occurrences and devastation created by these landslides. There is no historical record of one such mishap that had blocked the river about 30 km downstream from Gangotri near Jhala. Here, the Dhaini hillock fell down into the river bed and created a 10 km lake from Jhala to Jagla where the Bhagirathi flows very slowly and gives the evidence of the formation of the lake. This information is contained in a folk song and was confirmed by the excavation of an old Shiva temple in Dharali village. The folk song mentions the existence of 240 temples in that area in the past. Other landslides that occurred in this century are that of Sera, which blocked Jalkur in 1939, and Loharinag and Ddabrani in 1959 and 1978, respectively, blocking the Bhagirathi. Large-scale occurrence of landslides takes place when the recent cracks are filled with water during the monsoon. This shortens the life of the reservoir.

Economic Aspects

One of the arguments advanced in favor of the continuance of the Tehri dam project, in spite of all the hazards, is that an amount of Rs 650 crores has already been spent on this project. It is essential to examine this expenditure in the light of the Comptroller Audit General (CAG) Report of 1986/87. A fresh and up-to-date special audit of the project by the CAG needs to be ordered to find out the propriety of expenditure incurred on different items. It is strange that during the first 10 years of work on the project, in which, besides construction, some rehabilitation was also carried out, a sum of Rs 300 crores was spent; but, within the last three years, since the project was handed over to the Tehri Hydro Development Corporation, a larger amount than that has been spent...However, even if the project is replaced with the 'run-of-the-river' scheme, most of the expenditure incurred so far need not be written off. The Tehri town, the buildings and the roads that have been constructed, and the machinery which has been purchased can still be utilized. The money paid as compensation is no loss as most of the people are prepared to return the money. In fact, the present value of lands acquired in Athoor area, for instance, is 200 times more than the compensation paid to the farmers.

The economic aspects of the project should also be examined from a different angle. The local people who stand to lose the best flat land of the Bhagirathi and Bhilangana valleys wondered how they are going to be benefited by the Tehri Dam project...Tehri Garhwal is the poorest district of India according to the first Interstate and Interdistrict Income Differential Report produced by the National Council for Applied Economic Research in 1956. In the hills, there is one hectare of land for 17.6 persons and, out of it, the flat and irrigated land is very little. Area under irrigation in the district is only 12% of the total cultivated area. The people enjoy free irrigation and fodder and fuel from the community forests. Though per capita holdings are very small, for one hectare of cultivated land, 11 hectares of forest and community land are available. We are, therefore, pushing these innocent people, who have been self-sufficient farmers for centuries, into the cruel hands of the market economy, where their survival is at stake. Till now, the people residing in the hills enjoyed peace and security in their environment but now they find themselves insecure in the foothills, where 10% of the total oustees of the Tehri Dam project were already settled 10 years ago. The Bhumla Committee, which has visited this settlement, presented a pathetic description of their plight.

The claims of the project authorities to supply irrigation water to the command area and drinking water to Delhi need to be reexamined in the light of Report No. NA-4-755 9/3 dated 18 October 1991 of the Soviet Ministry of Environment submitted to the Government of India.

The Bhumla Committee has, at length, dealt with the adverse effects of the project on the proposed command area. At least 20 000 hectares will be trapped in the reservoir after the construction of the dam. It will also throw thousands of the small *Patta* peasants out of employment who depend for their survival on the flood-prone land on which they cultivate vegetables after the floods recede. There will be no flushing of the Ganga between Narora and Allahabad where it resembles a dirty *nalla.* All efforts made by the Clean Ganga Project will be nullified if the monsoon water is not allowed to flow into the river.

This project will also create regional imbalances. After the submergence of the valleys, which are at the hearts of the hills, and the export of the water, there will be no opportunity for the hill villagers to regreen the naked slopes, which is the only way to alleviate their poverty, check soil erosion, manufacture new soil for the plains, and stabilize the flow of the river.

Cultural Aspects

The cultural aspect has also been totally ignored so far. For the people of India, the Bhagirathi has a special spiritual significance, as the river reminds them of the high ideals of penance, and the selfless service with which the story of its origin is connected. The Bhagirathi binds the whole country into one unit. All the places connected with the great Vedantic saint, Swami, Ramatirth Padivargaon Kutiya, the Bamrogi cave, the Malideval Kutiya, and the Simlasu Kothi will be under water. There can be no substitute for this loss because the future generations will be deprived of the inspiration which these places provide, the inspiration which created people like Lal Bahadur Shastri and Swami Raman Tirth – two great servants of the people.

There are many more points which need to be considered because the affected people in the submergence area, and, even in the command area, for which a disaster-management plan was to be prepared, were never given a chance to put forward their point of view. The first attempt they had made was through a petition submitted to Lok Sabha in 1977/78.

The reports of the Roy Committee and Bhumla Committee may serve as the basis for a review of the Tehri Dam Project. The evidence of scientists recorded by the Bhumla committee in this respect should be minutely examined. Independent opinion regarding seismic activity in future earthquakes can only be of those seismologists of this country and other countries who have not in any way been connected with the formulation and clearance of the Tehri Dam Project, either in the capacity of consultant or chairman or member of any committee constituted for these purposes.

Now the composition of the Review Committee should be such that besides scientists and experts of different disciplines, seismologists, sociologists, economists, ecologists, spiritual leaders, and members of Parliament should also be included. We hope that such a committee will reach a unanimous decision and will protect this unique heritage of humankind, which is being ravaged for short-time economic gains simply because the concept of economic growth believes in the religion of economics and the ritual of technology.

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POPULATION DYNAMICS, ENVIRONMENT, AND CONFLICT

Ismail Serageldin[1]

INTRODUCTION

> *In the history of Western thought, [people] have persistently asked three questions concerning the habitable earth and their relationship to it. Is the earth, which is obviously a fit environment for [human] and other organic life, a purposefully made creation? Have its climates, its relief, the configuration of continents influenced the moral and social nature of individuals, and have they had an influence in molding the character and nature of human culture? In his long tenure of the earth, in what manner has man changed it from its hypothetical pristine condition?*
>
> Glacken (1967), quoted in Goudie (1993: 1);
> [people] and [human] substituted [men] and [man] in text

Glacken's second and third questions have not been fully answered. Indeed, the 'genesis' notion which set humans above and against nature, entitled to rule like absolute despots, was 'formulated into a philosophy of science and progress by men like Baccon, Galileo, and Descrates' (Goudie 1993: 2). In their conscious or unconscious attempts to change their environment, human values and cultures are being equally changed. The chain of change – from people's prevailing values, technologies, and institutions, to changing environment, leading, in turn, to change in values, technologies, and institutions – creates pressures and unequal opportunities, leading to potential conflict among and within human societies, and between people and their environment. One of the important forces in this chain of change, that leads to potential conflict, is that of population dynamics. This paper focuses on population changes leading to environmental change and potential conflict.

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Population dynamics is a discipline that deals with the determinants and consequences of changes in the structure, growth, and distribution of populations over time. By structure, we mean the distribution of a given population by age and gender. There are two concepts of population growth. The first relates to a total change in population relative to a base population size. Total change includes the balance of births, deaths, and net international migration in a given period of time and within a given national boundary (conventionally called the rate of population growth). The second is defined as the natural rate of population growth. This natural rate of population growth focuses on differences in the vital rates of births and deaths, and excludes international migration as a source of increase or decrease in population size. Indeed, in the case of a 'closed population', the two rates are equal. Internal distribution refers to the spatial distribution of a population within a national boundary, such as rural–urban or regional balance within a country. It also relates to measures of density. As will be evident from the following discussion, population growth, structure, and distribution constitute a consistent and interrelated demographic subsystem of society. They are also an integral part of the larger social, economic, and environmental system.

The purpose of the present paper is to investigate the role of these basic demographic phenomena as a source of social and political conflict or disorder. Harmony and order are not the norm in a world of continuous and accelerating changes in technological and environmental conditions. Many of these changes are not confined to their areas of origin. Furthermore, not all changes are predictable. Many could be sudden, radical, and uncertain. Recent developments in multimedia and information technology are examples of rapid technological changes with many unexpected and as yet unforeseen worldwide socioeconomic, legal, and political ramifications. Uncertainty is illustrated by changes in environmental conditions that were thought to be relatively stable and predictable as indicated by the case of the Greenland ice cores. Systematic observations of these cores questioned the conventional view of the stability of climatic conditions over long periods of time. Considering such observations, J Piel concluded that 'climate can change suddenly and radically' (Piel 1993: 16). Will we have time to adapt to such unforeseen environmental and technological changes, especially where many of the consequences seem to have no respect for national boundaries? What is the role of population change, as a cause and effect, in this era of uncertain change? More specifically, are there patterns of population change that reduce the adaptive capacity of the system to deal with conflict? These are the questions that lie at the core of the present discussion.

By the adaptive capacity of the system, we mean the extent of society's technical and social sustainability. Technical sustainability implies the ability of society to maintain, over time, the productive capacity of its core resource endowment. Social sustainability implies the harmonious evolution of its social contracts and of the *institutions* necessary for the enforcement of these contracts, within and across generations, in the face of such changes. The dichotomy of the adaptive capacity of the social system into technical and social spheres parallels that of the material and 'ideational' antecedents of institutions. As McNicoll put it

> *Institutions ..emerge or are designed as ways for people to deal with recurrent problems about material realities (resources, technologies, environmental conditions, human biology) and as manifestation of ideational systems that give some degree of coherence in the cultural domain of symbol and belief* (McNicoll 1994: 6).

The main argument of McNicoll (1994: 7) is that institutions are path-dependent. They are

> *. a precipitate of time. They adjust (admittedly with some delay, and at times only, so to speak, with considerable provocation) to changing circumstances – say, shifting power relations among social groups or altered transaction costs. But the direction in which they adjust depends not merely on those new circumstances but also, and crucially, on their past history.*

From the perspective of the present discussion, the adaptive capacity of society, especially as it relates to conflict, is a function of the mechanism by which institutions evolve. The question as to how institutions evolve is yet unsettled. The recent research program in sociology (e.g., Michael 1983), which attempts to illustrate that institutions emerge from behavior, seems to be, on the one hand, an attempt to indicate the universality of a standard explanation or theory to all institutional settings, and an overly optimistic program, on the other hand The parallel in economics is the attempt to impose the atomistic Newtonian paradigm of the equilibrium of forces, with possible growth but no genuine qualitative change in society, as the universal explanation of social and economic evolution It could be argued that the atomistic Newtonian paradigm, as a philosophy, has its origin in preSocratic Greek philosophy, in particular that of Anaximander. Anaximander believed in the existence of an equilibrium of forces whose final outcome is an optimal state of justice, however, his system is not fully deterministic He allows for uncertainty in his evolutionary paradigm

> *Anaximander offers an underlying metaphysical principle that explains the surface appearance of things. For the implication may be that the changes and conflicts, the give and take that we observe occurring every where in nature, are parts of a process of* exploration and reparation

> *that, in the long run, maintains an equilibrium or a state of* 'justice' *in the whole* (Collinson 1990: 5–6, emphasis added).

In the atomistic Newtonian paradigm, social structures are incidental. They are merely the children of a system of microbehavior that is always consistent, optimal, and independent of time. Recent literature on the behavior of the government as a social and political institution, which represents collective behavior, is illustrative of the incidental nature of structures in this paradigm. In that 'positive' framework, the evolution of the government is a result of agents' maximizing behavior, i.e., to maximize their length of stay in power or their budget, subject to existing resource and power constraints. These constraints, mainly exogenous, are set by the existing distribution of wealth and political power. Indeed, under special and rather strict conditions of perfect competition in the economic, social, and political domains, the two types of welfare maxima, atomistic and collective, may coincide; however, the world is imperfect. The causes of the imperfection are outside the paradigm. Understanding the sources of the constraints, whether economic, social, or political, is the study of the structure of institutions. In the absence of such analyses, development is reduced to *atomistic* behavior on the margin.

The limitation of the atomistic paradigm has been discussed extensively in the literature (e.g., McFarland 1991). Many economists have been wary of the indiscriminate application of standard theory to development economics. This is best illustrated by Georgescu-Roegen (1971), who warned against the universal application of the Newton–Smith equilibrium paradigm without regard to contextual differences, especially to the case of developing countries

> *For the tenacity with which we cling to the tenet that standard theory is valid in all institutional settings – either because its principles are universally valid or because all economic systems are mixtures of some invariable elements – has far-reaching consequences for the world's efforts to develop the economy of nations which differ in their institutions from the capitalist countries. These consequences may go down in history as the greatest monument to the arrogant self-assurance of some of science's servants* (McFarland 1991: v).

The focus of this paper is to examine the role population dynamics plays in influencing such adaptive ability. Our main claim is that social and political conflict is a function of the adaptive capacity of society. We argue further that the effect of population change on society's adaptive capacity is context specific. No general theory exists that encompasses all situations. The real world is inconveniently complicated. Analyses can only produce conditional and tentative conclusions that are short of universal generalizations.

The effect of population change on society's adaptive capacity depends, among other things, on the structure of the social, ideational, and political systems. That *structure* includes, for example, the degree of society's ethnic and cultural homogeneity and the degree of equity in the distribution of its income, opportunities, and political power. The effect of population change depends equally on the ability of existing *institutions* to introduce necessary changes and, meanwhile, have themselves the capacity to adjust to such changes. We agree that the evolution of institutions is path-dependent. The atomistic Newtonian paradigm needs elaboration as to how history, present circumstances, and expectations *interact* to influence institutions through the *aggregate* of individual decisions and behavior. There are three sets of *institutions* that, for purposes of the present discussion, define the social structure of society: government and governance, economic, and social institutions.

POPULATION TRENDS AND THE DEMOGRAPHIC SYSTEM

In this section, we review some key population trends. The review serves as the basis for interpreting the consequences of these trends. To facilitate the discussion, demographic concepts are defined and some basic demographic system identities are introduced. The relation between population change and conflict is a policy-oriented subject. Policy analyses include four levels: descriptive, explanatory, predictive, and evaluative. Formal demography provides the tools and technical language to measure and describe the levels, movements, and interrelations among the three basic components of population change: mortality, fertility, and migration. Descriptive demography also provides population projections. These are essentially scenarios that specify, given the initial age structure, the boundaries and limits within which population change could occur over time. The level of explanation, prediction, or the cost–benefit evaluation of demographic phenomena, however, is beyond the basic tools of technical demography. Here, demographic analyses must join hands with a large number of other methodologies and disciplines that range from biology, economics, and sociology to political and environmental sciences.

A simple but fundamental demographic accounting identity relates population growth r(p) to its basic components as follows

$$r(p) = \text{Crude birth rate} - \text{crude death rate} + \text{net migration rate, or}$$
$$r(p) = CBR - CDR + NMR \qquad (1)$$

The size of r(p) depends on the difference between the two vital rates of birth (CBR) and death (CDR), assuming international migration (NMR) is not a significant factor. Not immediately obvious, from equation (1), is the presence of a direct relation between the level of fertility and the age structure (or the age pyramid).

High fertility that persists for a few generations produces a young age structure where the bottom of the age pyramid is fairly wide. In this situation, the young, say those under age 15, compose a large proportion of the population, typically 40% or more, compared with about 20–25% in societies with older age distributions. Whereas the old, say 65 and older, make up less than five percent of the total population compared with 15–20% in older age structures. This pattern of high fertility and young age structure has been the typical case in almost all the developing countries through the 1970s. With fertility continuing at relatively high levels, the remarkable decline in mortality that started in the 1950s did not have a significant effect on the young pattern of the age distributions in the developing countries. Its main effect has been to produce high rates of population growth.[2]

A systematic decline in fertility in some developing countries started in the late 1970s. It was led mainly by East Asian countries: Korea, Taiwan, China, Hong Kong, and Singapore experienced a remarkable decline. These were joined more recently by Thailand, Malaysia, and Indonesia. By the late 1980s, fertility in most of the developing countries, regardless of the level of their development or cultural background, seems to have started a sustained decline. On the whole, birth rates have declined by one-third since the mid-1960s: women formerly had six children on average, but only four by the beginning of the 1990s. This apparent trend led some observers to conclude that

> *The developing world is undergoing a* reproductive revolution. *In contrast to the classical demographic transition, recent evidence suggests that birth rates in the developing world have fallen even in* the absence of improved living conditions. The decrease has also proceeded with remarkable speed. Developing countries appear to have benefited from the growing influence and scope *of family planning programs, from new contraceptive technologies and from the educational power of mass media* (Robey, Rutsien, Morris 1993: 60).

Some observations on this '*reproductive revolution*' are in order.

1 These trends are not universal. As indicated in Figure 1, the decline in fertility has been lagging in some regions and countries, i.e., sub-Saharan Africa and some Arab and South Asian countries. It is true that family

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[2] For more details about the demographic transition, and an explanation of demographic concepts, see World Bank (1984), and the World Bank (1993) for the health transition.

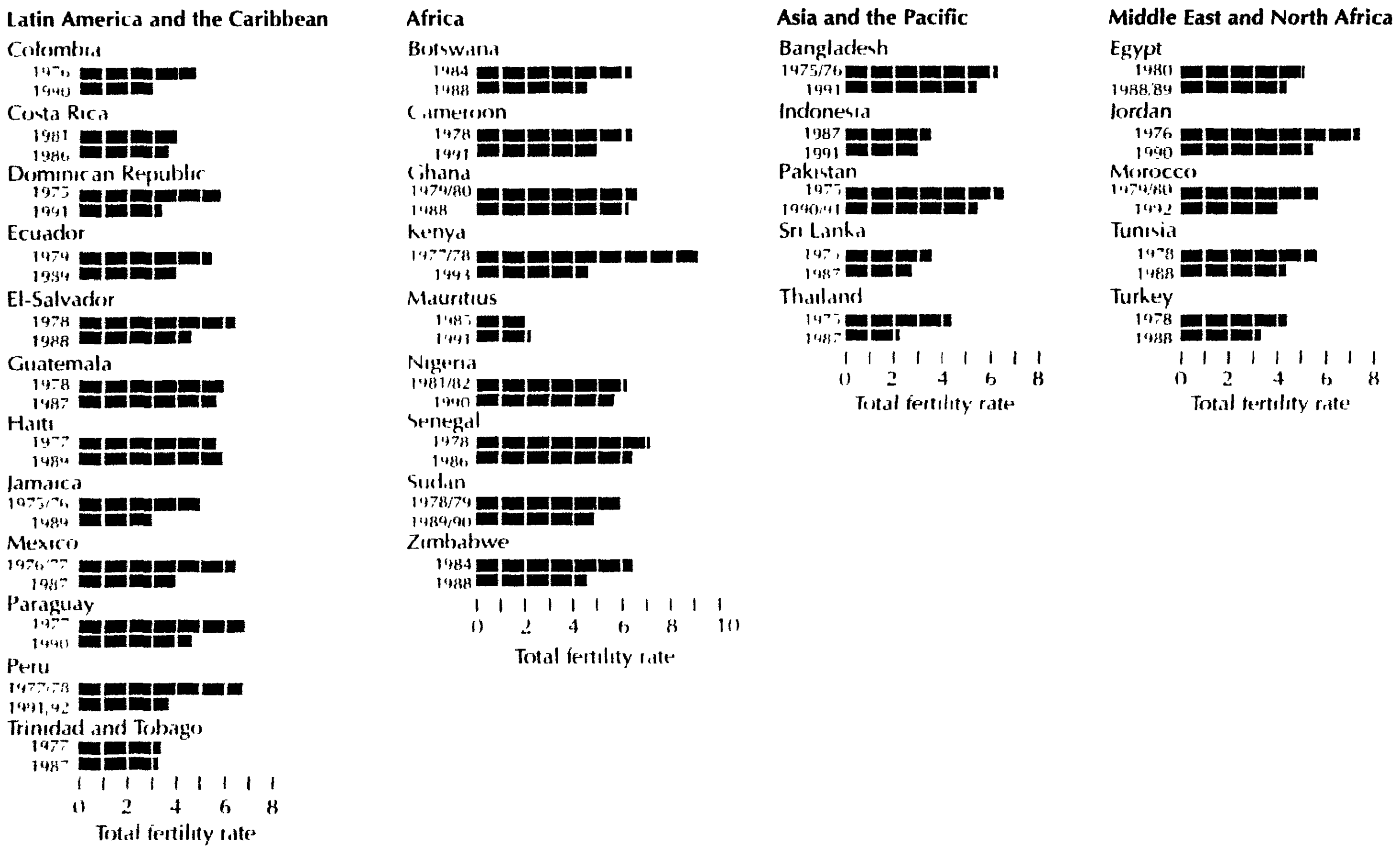

Figure 1. *Fertility rates and their relation to education and birth control in some developing countries*

Source Robey, Rustein, Morris (1993)

planning programs have influenced the fertility decline. The size of the *net* effect, however, especially its independence of the level of development, is open to question. For example, Bongaarts, Maulding, Phillips (1990) conclude that the absence of family planning programs worldwide would have led to an increase in the total fertility rate of the low income countries by 1.2 children over its 1989 level, or about 60% of the total fertility decline experienced by these countries. In contrast, Schultz (1993), using pooled cross-sectional data and estimating a reduced form equation, finds a relatively insignificant net effect for family planning programs

> *...if the mean level of family planning score had not been 34 but zero, the associated total fertility rate would have been 0.3 more* (Schultz 1993).

Schultz acknowledges the presence of various styles of development that are associated with different sets of structures and constraints, and modeled fertility behavior subject to some structural constraints. However, the analysis falls short of presenting a theoretical underpinning of the role of institutions in the evolution of these structures. This theoretical gap could result in errors of specification and of interpreting the results. For example, the hypothesis that countries with rich oil reserves will act within a microbargaining framework ignores how government and political institutions function. The emerging system of 'incentives' is a compromise between political and ideational forces. Its consequences to fertility are context-specific and often mixed. (Sirageldin 1992). Also, disregarded is the role of ideational institutions. Once a significant relation between economic constraints and fertility in Islamic countries was found, Schultz hastened to dismiss the relevance of ideational and cultural institutions. He concludes

> *The relatively high levels of fertility in Islamic countries are explained here in terms of the underlying economic constraints on the population, including past educational investment in women. One does not have to resort to* ad hoc cultural variables to explain most of the variation in fertility across low income countries (Schultz 1993: 30).

Institutions were not part of Schultz's paradigm. Schultz's statement is based on a 'pure' neoclassical paradigm that regards *economic* incentives as the supreme power that shape micro *socio*economic behavior.[3] This view is probably true in the long run since institutions do adjust eventually. It is important, however, to understand the determinants of institutional rigidities. Institutions that do not adapt, even for short periods, could impose high social costs in the longer term. For example, the delayed fertility response in Syria to a high degree of social change that included a significant improvement in the status of women is probably adding constraints to the country's development possibilities (Courbans 1994).

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[3] It is somewhat puzzling that models of household behavior continue to be formulated in the neoclassical tradition of assuming a purely competitive market with a perfect clearing mechanism, while recent developments in other areas of 'hard-core' economic analyses question whether markets are the best institutions available? See, for example, Allen, Gole (1994).

McNicoll (1994), on the other hand, argues convincingly that institutions should be an integral part of fertility analyses, even at the cost of less formalism. Variation in fertility trends is expected because institutions differ significantly among the developing countries. He presents a fivefold typology of broad patterns of fertility transitions. Patterns of transitions depend on the types of existing institutions. We must be wary of generalizations, McNicoll cautions.

2. Despite the observed decrease in birth rates, the world population will continue to grow at high rates. It is expected to double to 10 billion by 2050. For some countries, the increase will continue well through the middle of the next century. The reason for the large increase in population size in the face of declining fertility rates is the '*momentum*' built into the young age structure of the populations of the developing world. For example, if India adopts a replacement level of fertility immediately, its population will continue to grow until the sizes of its various cohorts equalize, thus reaching a *stationary* state. In this transition, India's age structure will change from its original young 'triangular' shape towards a stationary 'rectangular' shape, as illustrated in Figure 2 (a and b).
3. Population will increase in size when moving from a young age structure, typical for all developing countries, towards a stationary state. That increase will be greater, the 'younger' the initial (stable) age structure. Furthermore, that increase in population size will be concentrated in that part of the population which is above 30 years of age. This process is illustrated in Figure 2 for the case of India. In this hypothetical case, between 1995 and 2025, the *size* of the 30–35 age group can be expected to increase from about 70 to 100 million people. In this scenario, for those who are less than 10 years of age, population size declines from about 230 to 210 million.[4]
4. The socioeconomic significance of the concentration of growth in the older age groups (over 30 years old) needs no emphasis. It is probably a major source of conflict in the process of population change. It increases the supply of potential workers in society. It also increases the relative claims of the elderly. If output and productivity do not increase fast

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[4] For a technical statement about momentum that proves that the population under 30 does not change significantly in size, see Young, Schoen, Sarma, (1991).

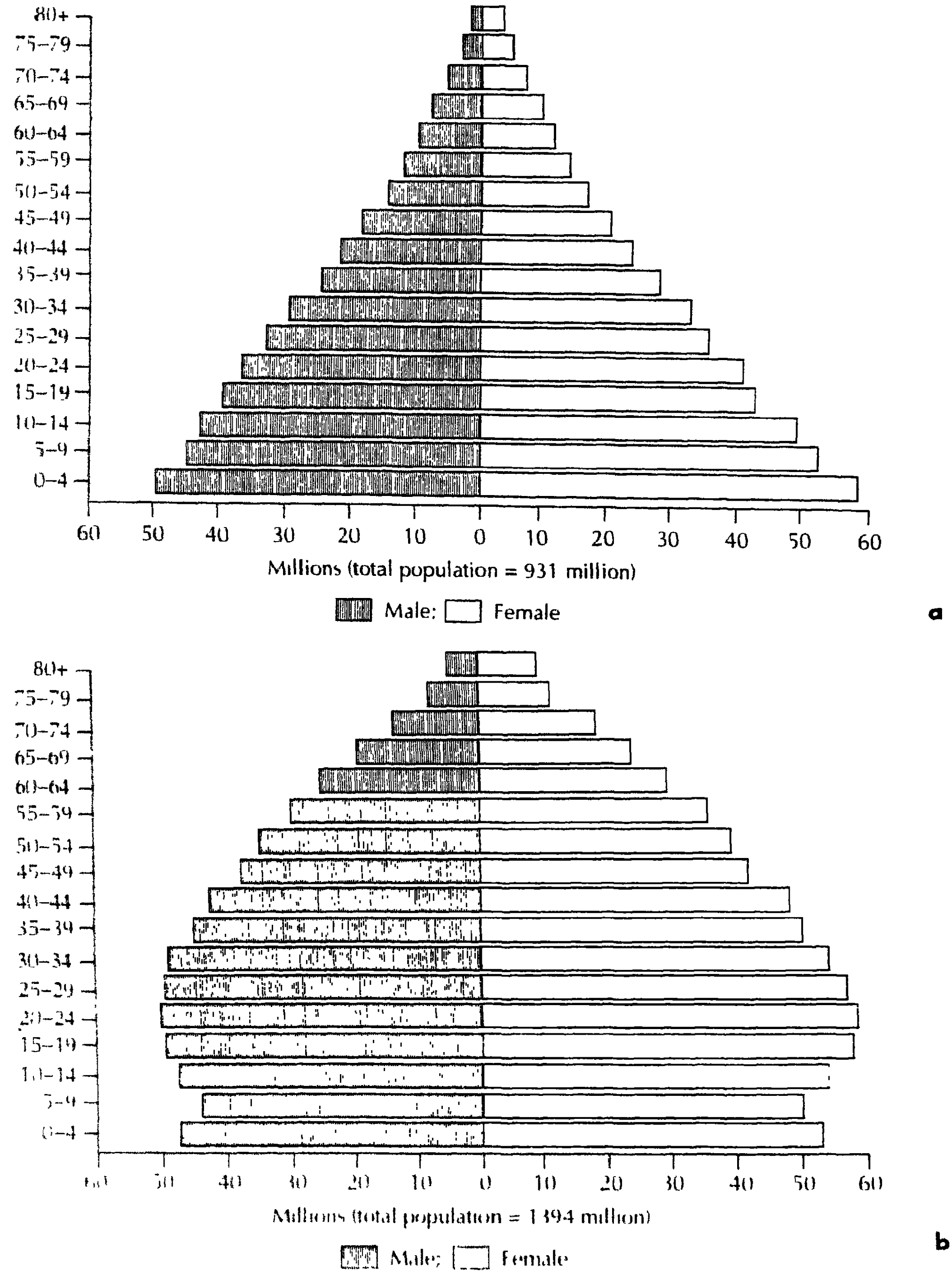

Figure 2. *Projected age structure of India;* **a** *1995,* **b** *2025*
Source UN (1993)

enough, unemployment, forced population movements, and the potential for intergenerational conflict mav arise. These negative consequences of an aging population could reduce the prospect for development. In that respect, an exogenous decline in fertility that is independent of the level of development, as observed by Robey, Rutstein, Morris (1993), should not be a cause for unqualified celebration. Fertility reduction is not a development objective. It is one of the instruments used by a society to achieve higher levels of welfare. To represent a viable paradigm for development, such exogenous fertility reduction should generate its own internal dynamics for development – a process not well articulated in theory or fact, especially when recalling the experience of the developing countries with the mortality transition. Otherwise, we are left with a worse-case Malthusian world, where the socioeconomic burden of an ageing society is added to the usual Malthusian case of a costly struggle between reproduction and production that revolve around marginal subsistence, famine, and social conflict. Such a case was labeled a 'standstill' scenario, in contrast to a fertility reduction that is part of a sustained 'development transformation' (Sirageldin 1991).

5. Concentrating on fertility and its effects on the age structure ignores other important consequences of fertility decline An established high level of fertility reflects a structure of local values, traditions, and social contracts. That structure represents the foundation and stability of the existing social and political order. It is both a consequence and a cause of an established distribution of income, wealth, power, and authority. New patterns, especially those perceived as foreign, pose serious challenges to the privileged status of the existing authorities. Such challenges do not proceed without resistance. It is emphasized that, even in social structures that have been established for long periods, values are not universal. At any time, there exists a certain degree of value heterogeneity. This should not be confused with the continual changes in the 'overall' value system being induced through innovations and technical change. Institutions, using McNicoll's (1994) terms dealing with material realities, *evolve* as a result of the introduction of new technologies or of changes in environmental conditions. Changes in material conditions are associated with changes in the distribution of wealth and privileges. These changes require a parallel evolution in the ideational institutions to rationalize and give coherence to the new distribution of roles and privileges. The two institutions, material and ideational, must evolve in concert. If changes in the material sphere are sudden, large, or proceed at a fast pace, adjustments in ideational institutions could be resisted or lag behind. The result mav be costly conflict.

   The policy challenge is to maintain the diffusion of social and technological innovations within the ability of society to absorb its 'new' value implication. That challenge is not always met, partly because *the institution of government* is not free to act independently of the distribution of political and economic power, whether internal or external. Who benefits from the state's action cannot be inferred *a priori* from the atomistic paradigm

> *If such development-induced change proceeds too fast, relative to the ability of the social system to absorb it [to become endogenous to society], resistance to change may turn into revolt against change and ignite revolution against the established regime. The result of these dynamics could be* the emergence of a new development paradigm that builds upon threatened traditions, or an attempt by the established regime to accelerate the process of change...*Established regimes may fear the loss of legitimacy and may divert scarce resources to security issues through costly repressive means or through a nonsustainable system of subsidies and employment guarantees, away from their countries' long-term development priorities. Alternatively, established regimes may seek alliances with foreign powers that on the surface seem to be an attempt to accelerate the modernization effort, but mostly are attempts to seek protection against the opposing forces that represent established traditions* (Sirageldin 1992: 50).

6. Migration is the third element in the demographic accounting of Equation 1. Migration is probably the most important population factor underlying the overall stability of the socioeconomic system, at least in the short run. In its free perfect market scenario, migration, by responding to market signals, improves the overall efficiency of the economic system. Imperfection in market behavior that restrains change and reduces factor mobility leads to efficiency losses. For example, resistance to change depends on

   > *...the structure of the social system, the degree of its openness, e.g., acceptance and assimilation of immigrants. A tribal social system, a commune Chinese-type, a canton Swiss-type system, or a subsistent rural community are examples of relatively closed systems with strict socialization processes that limit the domain of individual mobility* (Sirageldin 1992: 50).

   The control of immigration as a legitimate exercise of national sovereignty is not much disputed in international law and relations; however, such movements, whether legal or not, do occur on a large scale. In many instances, the results create conflict and violence. For example, it is estimated that in 1992, there were 21.6 million refugees around the world. These were distributed as follows: 9.89 million refugees in Asia, 5.39 million in Africa, 4.38 million in Europe, 1.04 million in North America, 0.89 million in Latin America, and 0.06 million refugees in Oceania (PAI

1994). Movements of refugees are partly a result of conflict in areas of origin and a cause of conflict in areas of destination. The relation between international (*or internal)* migration and conflict is well established. Causes include lack of cultural, political, or economic integration (Arsdol 1985; Choucri 1984).

It must be noted, however, that although the economic and social consequences of migration seem current and visible, its determinants could be a result of deep-rooted historical foundations. It could be triggered by unexpected and sometimes irrational incidences creating costly conflicts. There are many such examples in recent history as well as in today's world.

MODELING POPULATION CHANGE AND CONFLICT

POPULATION AND DEVELOPMENT

Population dynamics is a subsystem of the larger socioeconomic system. The demographic identity of Equation 1 could be incorporated in a larger identity that relates population growth to the growth rate of national output. That latter rate includes the rate of *net* human and physical capital accumulation as follows

$$r(p) = r(Y) - r(y) \tag{2}$$

$$r(y) = (S/K) - (CBR - CDR + NMR) \tag{3}$$

where r(p), r(Y), r(y), S, and K refer to rates of growth of population, gross national product (GNP) and per capita GNP, the saving ratio, and the incremental capital output ratio, respectively (Sirageldin 1991).

On a descriptive level, the left-hand side of Equation 2 indicates net human capital formation (additions to population with a given composition of knowledge, skills, and abilities) and the right-hand side indicates physical capital accumulation. Equation 3 illustrates that to maintain the same living standard of $r(y) = 0$, invested saving (S) and productivity (K) must provide for net additions to the population r(p).

However, development implies more than accommodating net additions at the same standard of living. It implies an attempt to improve living standards for present and future generations. Representing the gap between current and desired status by 'd', Equation 4 represents required system adjustments as follows

$$d\,[r(y)] = d\,[(S/K) - (CBR - CDR + NMR)] \tag{4}$$

Although an identity, Equation 4 indicates that to accommodate the desired change, adjustments must be made in the socioeconomic, demographic, and technological components of the system. Regardless of the model employed, these are not marginal adjustments of socioeconomic processes (Sirageldin 1992). They include basic interrelated structural transformations: human capital, agricultural, technological, and institutional, among others.

An example of the interrelation between demographic and agricultural transformations is given in Sirageldin (1993). Both transformations must act in concert. It seems rather impossible to increase labor productivity in agriculture significantly, for example, through a massive mechanization program without an equally massive spatial and occupational mobility in the short and medium terms, and a parallel decline in fertility to insure stability in the longer term. (Sirageldin 1993). The interactive nature of migration and fertility on the stability of the socioeconomic system is often overlooked. For example, it was found that rural–urban migrants are selective on low fertility. The implication is that high rates of rural population and labor growth will continue for longer periods in the future. Accordingly, agricultural transformations that attempt to improve labor productivity through the adoption of labor-saving technologies will generate pressure on the nonagricultural sectors to increase their labor absorptive capacity – a challenge that seems to fail more often than not. Ahmed, Sirageldin (1993) found significant selectivity bias by fertility among Pakistani migrants – rural–urban migrants were selected on low fertility.

The developmental policy challenge is to facilitate and achieve, with minimum social and environmental costs, a sustainable completion of these transformations, by minimizing the imbalances between the two basic accumulations of human and nonhuman capital. Imbalances between human and nonhuman capital accumulation do occur, however, in the normal course of socioeconomic change. Population growth may exceed or lag behind the rate of nonhuman capital accumulation and the growth of either accumulation may exceed environmental tolerance. The question is: under what conditions are societies able to cope with imbalances without resorting to violent conflict? In many instances, within institutional and technological limits, societies can cope with demographic imbalances. A celebrated mechanism is through the evolutionary introduction of labor-intensive techniques in agricultural production that increase the demand for labor (cf. Boserup 1965).

Beyond such limits, however, where imbalances are associated with unemployed resources or unfulfilled aspirations, demographic forces take hold through increased mortality, reduced fertility, or forced migration. These may be associated with costly unrest and conflict, within or between countries, that reduce the society's capacity to deal with the imbalances and to develop. What are the conditions for such developments?

POPULATION AND CONFLICT

What is the mechanism through which population changes create conflict? Clearly, there is more than one mechanism: resource scarcity, migration, expulsion, decreased economic opportunities, or famine conditions. There are also many types of conflict: ethnic or religious conflict, deprivation conflict, or *coups d'etat*. There are also various conditions that may enforce the relation between population change and conflict: inequality in access to resources or opportunities, ecosystem vulnerability, inefficient or weak governance, and inefficient market functioning, among others. Population is but one variable in a series of political, economic, social, and environmental factors that can bring about turmoil and conflict. It is our view that the causal process that links population to conflict is contingent on the presence of these other factors. Two factors play important roles: unequal access to resources and the value imports of the modernization process in practice

Lack of access to two basic renewable resources, water and cropland, when combined with high rates of population growth seem to ensure serious conflict. Figure 3 based on Homer-Dixon, Boutwell, Rathjens (1993) presents a framework that links the various factors, including population, to various types of conflict.

The left-hand side of Figure 3 lists the three basic sets of factors that influence conflict *indirectly* through a set of proximate factors. These *indirect* factors include renewable resources (water and cropland), population change, and unequal access to resources. Negative change in these three sets of factors leads to increased scarcity of renewable resources. Scarcity of renewable resources increases the migration rate as well as migrants' expulsion. It also decreases economic productivity. The combined effects of these two *proximate* factors affect conflict directly and indirectly through their effects on the strength of the state. Migrants' displacement and productivity decline reduce the state's revenue while the state increases its spending as it deals with the deteriorating circumstances. The result is to weaken the financial and political ability of the state. The combination of forced migration, decreased productivity, and a weakened state leads eventually to deprivation, ethnic or religious conflict, and finally *coup d'etat*.

The strength of the Homer-Dixon, Boutwell, Rathjens (1993) framework (referred to hereafter as HBR framework) lies in its simplicity, clarity, and flexibility Although lacking some important feedback linkages, it serves as a starting point for the preliminary analyses of specific case studies. Important feedback linkages that are missing from the framework include those between environmental and population changes. These are illustrated by the dashed lines in Figure 3 (not included in the original HBR framework). A more detailed specification of the role of population dynamics was attempted by HBR

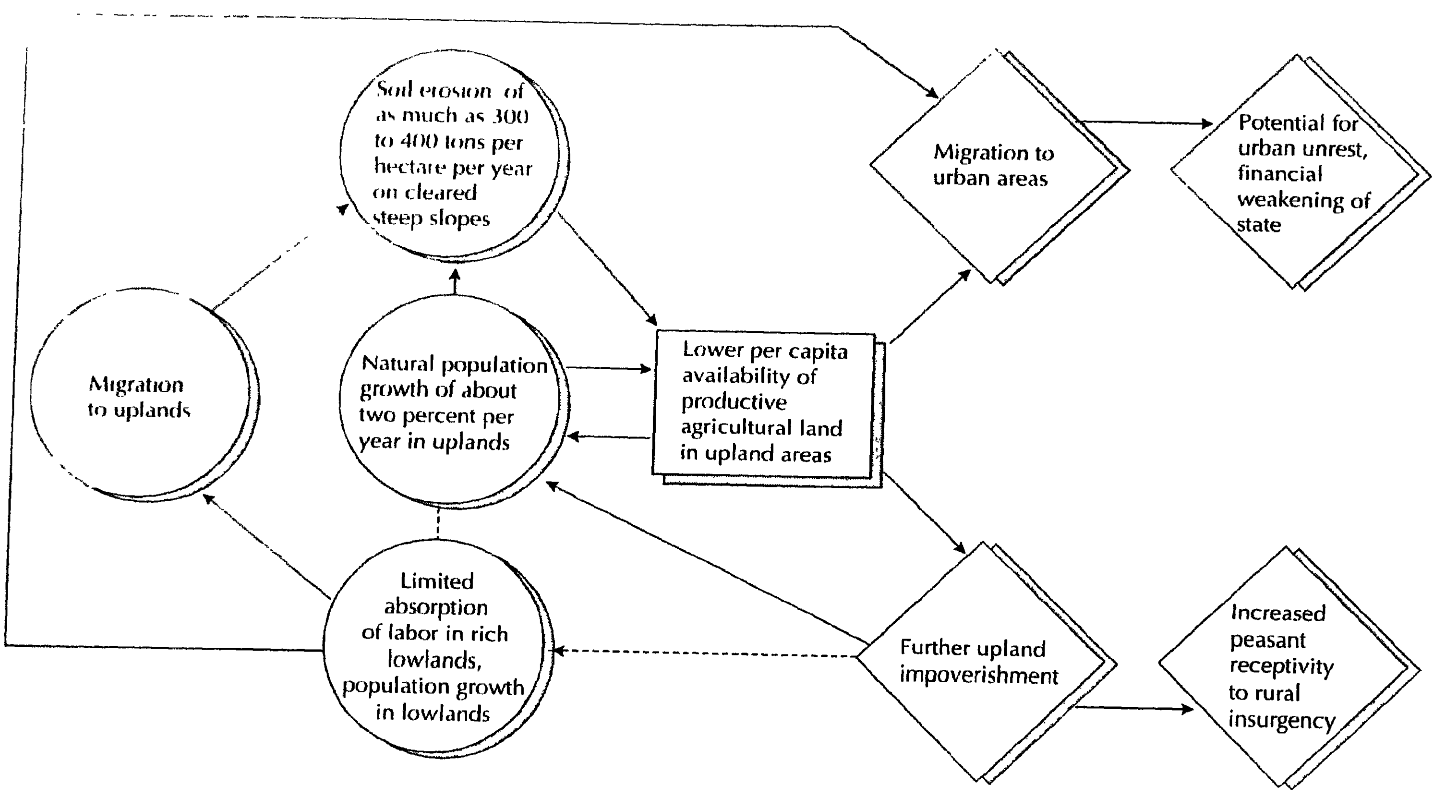
Soil erosion of as much as 300 to 400 tons per hectare per year on cleared steep slopes
Migration to uplands
Natural population growth of about two percent per year in uplands
Limited absorption of labor in rich lowlands, population growth in lowlands
Lower per capita availability of productive agricultural land in upland areas
Migration to urban areas
Potential for urban unrest, financial weakening of state
Further upland impoverishment
Increased peasant receptivity to rural insurgency

Figure 3. *Some sources and consequences of renewable resources scarcity. expanded model*
Source Homer-Dixon, Boutwell, Rathjens (1993).

in their analysis of the case of the Philippines. This is illustrated in Figure 4. Here, the population factors play a prominent role, however, their role continues to be exogenous to environmental and economic conditions. A fuller understanding of the role of population in this dynamic system should incorporate these feedback linkages (illustrated by dashed lines), however, the cost is an increase in model complexity.

The simplicity of the HBR model helped to focus on the main policy issues. It tells the following story about the Philippines experience. There are lowlands and uplands. The lowland is rich, has a high population density, and a high rate of natural increase. The lowland is exceeding its carrying capacity and provides limited labor absorption capacity. People from the lowlands start emigrating to the uplands; however, the natural rate of population growth in the uplands is already high. The result is more cultivation of steep slopes, increased soil erosion, and reduced per capita availability of productive agricultural land in upland areas. Upland welfare deteriorates, upland populations become less receptive to immigrants, and migration streams are redirected towards urban centers. The combined effects of these forces led to conflict as outlined below

1. Migration from lowland to upland created resentment in the receiving area.
2. Both types of land experienced a decline in productivity, leading to the erosion of the state's tax base.
3. As a result of reduced productivity and labor absorptive capacity in both lands, migration streams moved to urban areas. The result is increased crime rates and deteriorating health and social conditions, leading to conflict.
4. The weakened economic and political status of the state limited its ability to deal with reduced agricultural productivity and to improve deteriorating urban socioeconomic conditions.

The story is revealing and fits the Philippines setting at the time. It also leaves some puzzling questions unanswered. There is a sense of unidirectional causation that suggests an inevitable outcome insensitive to economic or demographic feedback, e.g., see added dashed lines in Figure 4. What are the factors responsible for the absence or ineffectiveness of the feedback mechanisms that could provide signals to steer society from such a disastrous course? And, ultimately, what is the role of public policy in this scenario, especially in the early stages of its development? To answer this last question, the model needs to incorporate 'a theory of government' to introduce policy parameters and investigate farmers' and migrants' responses to such parameters. Reduced fertility today will not reduce the rate of growth of the labor force today or tomorrow. Jobs need to be created at an increasing rate to deal with the historic determinism of the age structure; however, postponement of the fertility decline will only exacerbate future consequences.

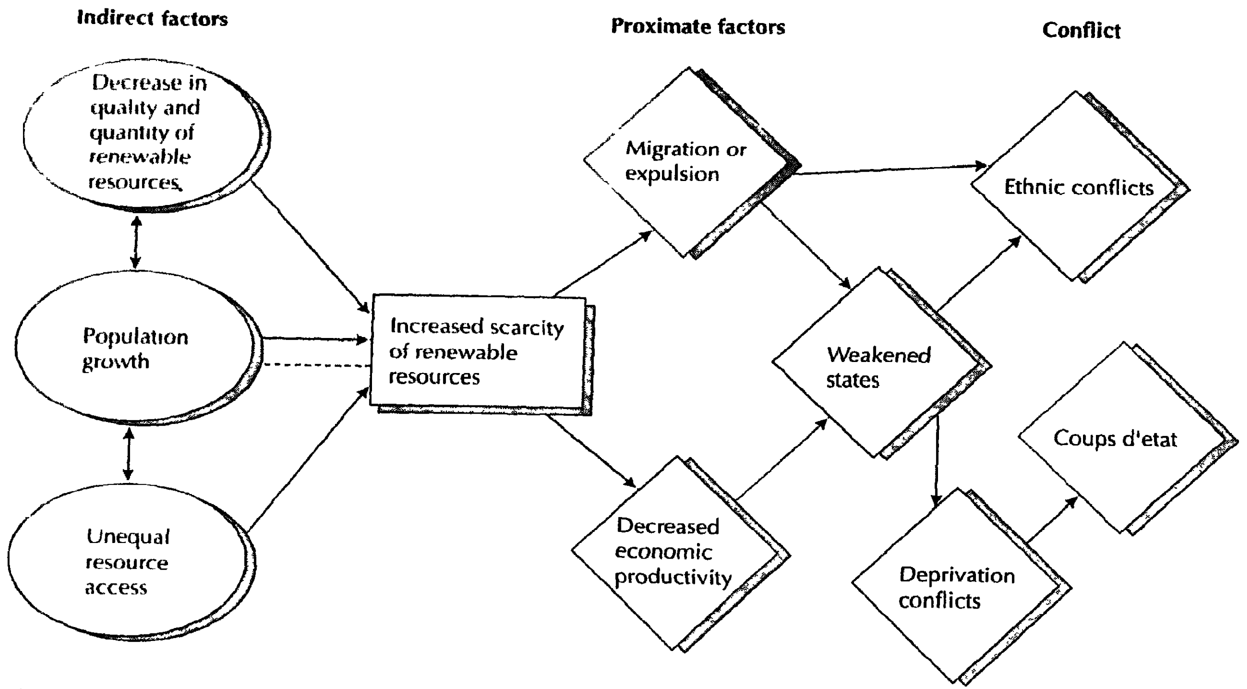

Figure 4. *Some sources and consequences of renewable resources scarcity*
Source. Homer-Dixon, Boutwell, Rathjens (1993).

What is missing from the HBR framework is the role of social values, ethnicity, religion, and racial tensions. These ideational factors are probably easier to use as control variables than to model. They also interact with economic and resource availability factors. Their net effects are hard to estimate or predict; however, they seem to be on the forefront of most of today's international conflicts. For example, there are many cases of religion related conflict in today's world. Although current, their roots go far back in history. The cases of Northern Ireland, Bosnia, and the recent polarization of Islam and Christianity as two cultures in conflict are illustrative. In a recent work, Huntington (1993) conjectured that future conflict in international relations will be based more on a clash between cultures or civilizations rather than between or among nation-states. Among the six dominant cultures in today's world, illustrated by Huntington as potential sources for future conflict, the confrontation between Islam and the West is illustrated by him as the most likely case (Huntington 1993). We disagree with various parts of the intellectual framework presented by Huntington, especially as it portrays the 'West' and 'Islam' as two homogeneous entities. Furthermore, it does not cover in sufficient detail the interactive nature in the development of the two cultures, that is, whether their historical paths were independent. On a more basic level, one may question Huntington's claim that clashes based on cultures or civilizations represent a *new* direction in international relations. The history of major conflicts, from the Crusades, to the World Wars, the Cold War era, or the North–South confrontation that followed, has been a history of clashes based on differences in ideology and systems of political economy that went beyond the nation-state. It is a history of the development of capitalism (e.g., Amin 1992). Huntington's analysis, however, is a good reading of historical events. It illustrates the role religion may play (or may be played with) in generating conflict on a worldwide scale. It is also a reminder that enhancing the adaptive capacity of institutions to deal with internal conflict goes beyond national boundaries.

The HBR framework is equally silent on the adaptive capacity of social institutions. How institutions evolve and adapt seems to be outside the framework. The aforementioned case of the Philippines illustrates this gap. The ability of institutions at various levels of authority (from individual to corporate) to anticipate and deal with these events, in order to minimize their negative consequences, was not discussed. Accordingly, important policy questions were left unanswered. Could *the state* play a more positive role in such situations? If yes, what would be the optimal scope, size, and timing of the state's intervention?

THE ROLE OF THE STATE

An important characteristic of a society that succeeds in reducing overt conflict is its ability to adjust to changing circumstances and take advantage of opportunities. The role of the state in promoting such an environment has become an increasingly controversial subject in recent years. For example, what is the degree of efficiency implied in the *markets* of Figures 3 and 4? And what is the role of the government in that case? The figures clearly imply a strong role for the state. This role is also implied in the Robey, Rutstein, Morris (1993) discussion regarding the efficacy of family planning programs with strong public support and commitment.

The weakening of the state is taken as a *result* of adverse economic and social conditions and a *cause* of the state's inability to act as an effective agent for development. However, adverse economic conditions inevitably lead to conflict that a weak state cannot resolve. Evidently, there is a dilemma as to the appropriate size and scope of state activities, especially in its role as an effective agent of development, while the present dominant economic ideology calls for minimal government

> *Dwindling natural resources can weaken the administrative capacity and authority of government, which may create opportunities for violent challenges to the state by political and military opponents. By contributing to rural poverty and rural–urban migration, scarcity of renewable resources expands the number of people needing assistance from the government. In response to growing city populations, states often introduce subsidies that distort prices and cause misapplication of capital, hindering economic productivity. Simultaneously, the loss of renewable resources can reduce the production of wealth, thereby constraining tax revenue. For some countries, this widening gap between demands on the state and its capabilities may aggravate popular grievances, erode the state's legitimacy, and escalate competition between elite factions as they struggle to protect their prerogatives* (Homer-Dixon, Boutwell, Rathjens 1993: 43).

There seems to be a general consensus that the state should promote the conditions for an adaptive economy. But what do we mean by a flexible or an adaptive economy? This is apparently a narrower concept than our earlier definition that included both 'technical' and 'social' sustainability and encompasses both material and ideational institutions. The term 'adaptive economy' has been discussed in great detail by Killick (1993)

> *Expressed in its own terms,* a flexible economy is one in which ends and means are readily adjusted to changing constraints and opportunities. *These include flexibility in the* institutional *base of the socioeconomic system, as well as* flexibility on the part of the government *in adapting* policy to changing conditions. *It implies an economy in which movement of resources among alternative uses is*

> *relatively low friction, low cost, and rapid, and leads to changing factor proportions, technologies, and composition of output...Given the* information and incentives, *the second set of conditions relates to* people's reactions to these stimuli, that is the responsiveness to economic signal (Killick 1993: 47, emphasis added).

Killick's definition of an adaptive and flexible economy implies a role for the state that is neither specified in size nor in scope, especially as it relates to his second set of conditions. For example, the state's responsibility in setting both *ends* and *means* is a controversial policy question of great social, political, and economic consequences. It is central to identifying the proper balance between *freedom and organization.* To illustrate, following Huntington's conjecture discussed earlier, a recent survey of Islam and the West as two competing civilizations (The Economist 1994) indicates the importance of the aforementioned policy question and the difficulty of providing a satisfactory answer for it. In that survey, the author argues that 'life in the late 20th century western world seems increasingly atomized'. The price of atomization, without moral guidance is increased isolation where people live as individual units rather than as members of a team, whether at home, at work, or even in leisure activities. According to that survey, the price of atomization in the Western culture is

> *...paid, in one way or another, by almost everyone: the breakdown of the family, people...grow more callous and more violent, the means of violence...are more readily available and more affordable, so are the things that tend to reduce self control, such as alcohol and drugs...This is why it is beginning to be argued that the West* must *find a way of putting individual initiative, the* necessary driving force *of progress,* within a shaping moral order, which is the only way of defining what the word 'progress' means (The Economist 1994: 17).

The issue of atomization as a value system goes beyond the Western notion of setting a high value on individual independence rather than interdependence. In its origin, this notion derived comfort from the Newtonian system of the equilibrium of forces at the margin. In their behavior, the Newtonian atomistic actors tend to converge towards an equilibrium solution that is always optimal, regardless of their initial arrangement. The operation of the system confirmed the metaphysical belief that individual actions are being guided by an invisible hand that always tends towards the best of all possible worlds. God with His vision of the 'good society' is in full control. This 'comfort and belief' in a 'controlled system' that produces the good outcome is being questioned. The system and its desirous outcome seems to be moving out of control. Individual behavior and its collective outcome seems to be controlled more by a value system of an emerging 'technical society' that elevates efficiency to a supreme status. The technicalization of a human society is essentially a dehumanization of that society. Progress is equated with efficient production without regard *for whom* or *what* is being produced. Even violence, whether on the individual, communal, or international levels, is being treated like any other commodity, and assigned a value that is proportionate to the efficiency of its production. In essence, the 'New World Order' is characterized by the emergence of a universal culture that is neither Western nor Eastern in substance. The consequences of this new culture to the peaceful coexistence of the human race, the survival of other species, and the sustainability of the environment are uncertain at best.

Should economics be silent on such issues of morality? Many economists feel that they should not. In an exhaustive survey, Hausman, McPherson (1993) take the position that economics should deal with moral issues. They argue that although economists in the last 20 years have renewed their conversation with moral philosophers

> *There remain considerable gaps between the modes of expression and habits of thought. [However] An economics that is engaged actively and self-critically with the moral aspects of its subject matter cannot help but be more interesting, more illuminating, and* ultimately more useful *than one that tries not to be* (Hausman, McPherson 1993: 723).

The West, the *Economist Survey* argues, could borrow from the moral philosophy of Islamic civilization, since

> *The distinguishing feature of Islam, which at the moment separates it from all of today's other would-be global cultures, is its belief not only that man's day-to-day visible life is surrounded by an invisible life but also that the two have to be kept in connection with each other* (The Economist 1994: 16–18).

This vision of Islam as a complete system that rejects a 'total separation between ethics and economics' is universally accepted among Muslim scholars (Sirageldin 1992).[5] This vision of Islam as a complete system implies a closer connection between the material and ideational institutions. Such close 'coordination' implies a strong *role* for the state – a *role* rendered more difficult in the presence of competing moral theories available for leaders and policy makers to guide their overall assessment of economic institutions and outcomes. In their survey, Hausman, McPherson (1993), list and discuss in some detail four kinds of moral theories: (i) those that focus on efficiency; (ii) libertarian theories; (iii) utilitarian or consequentialist theories, and (iv) contractarian theories. Their conclusions are illustrative

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[5] For a heroic attempt to present a complete and coherent Islamic economic system based on an axiomatic approach, see Naqvi (1994) and the paper by 'Islam, Society and Economic Policy' in Sirageldin (1996).

> *Few economists can avoid ever making appraisals of economic outcomes or institutions, and in making such appraisals they unavoidably rely on some moral philosophy... Very little in ethics is completely uncontroversial, and very little can be said about economics that relies on only uncontroversial moral premises. Economists concerned with evaluation are going to have their feet wet in the swamps of moral philosophy* (Hausman, McPherson 1993: 711–712).

Evidently, incorporating morality in economic management is vital but risky. Not surprisingly, the role of the state in promoting a 'moral society' was not discussed in the *Economist Survey*, especially as it relates to equity versus efficiency, or freedom versus organization, in the context of an increasingly competitive global economy. This trade-off has been at the forefront of political economy for centuries. Going back to ancient Greece, the question of the limits of government was mainly a debate between 'democratic participation' or giving the people control over public policy, and the ideal of 'isonomy' or the certainty of being governed legally in accordance with known rules. That debate seems to continue uninterrupted through the present time. It is isonomy or the 'Rule of Law' that Hayek (1955) seems to have elevated above the state authority and placed it as a justification for democracy. According to Hayek (1955: 34), for a legal system to be considered as constituting the Rule of Law, its 'laws must be general, equal, and certain'. The Rule of Law embodies the basic elements of the '*Moral Society*' and that should be above the state, and legislative authorities must adhere in some way or another to the 'general' will of the public, in order to be consistent, at least with Hayek's last condition: *certainty oj law* (a condition considered by Hayek as *supreme).* It is probably the *supreme* challenge of our present age of the 'new world order' to find a practical resolution between these two basic ideals: isonomy and democracy. One difficulty arises from the attempt by the state to cope with the consequences of the universality of new technologies and the level and scope of international competition. States may not afford to resist the new economic order. However, to accommodate it, while containing internal social and political conflict, they *tend,* with the likely blessing of the external economic powers, to impose more control and less democracy. This *tendency* has strong alliances from an emerging political economy that elevates market power above democratic participation, thus reducing people's control over public policy, a clear violation of Hayek's conditions for the Rule of Law.[6]

How much government is optimal? This is not an easy question to answer. As our previous discussion indicates: a weak government leads to conflict, and conflict leads to inefficient allocation of resources, that leads to weak government. However, more government may lead to inefficient resource allocation. It is not our purpose to go into the relative merits of market and planned economies. Such digressions often lead to conclusions that 'all for the best in the best of all possible worlds'. Evidently, there has been an increasing tendency in professional opinion, among politicians, and those they represent, to place more emphasis on market efficiency and mechanisms. Most economies continue to be mixed, however. We should be able to identify the critical policy parameters in such an environment. As Killick (1993: 49) emphasizes

> *However the balance is struck between the market and the state, we should note the importance of* adequate information flows.

Adequate information in this scenario improves the efficiency of the market and the political systems. This case was made strongly by Stiglitz (1988). An important role for the state, accordingly, is to improve information flows. We must be wary, however, of the possibility that free information flow, even in the present age of revolutionary communication technology, does not necessarily imply equitable utilization or reliable content. Information is often used, selectively, as a tool to serve political objectives even in established democracies (recall, for example, the use of the term 'misinformation' to justify the presentation of 'lies' in public announcements to promote governments' policy objectives during the Cold War era and beyond). Of more direct concern to the present discussion is that, in many instances, people and small communities in the less developed countries, that are most affected by the negative consequences of large public and private projects, such as irrigation dams or chemical complexes, and who should share in the implementation decisions of such projects, are not well informed about consequences. This state of affairs has generated a heated debate about many World Bank projects undertaken in the 1970s and 1980s. It led to the establishment of the Environment Division at the World Bank and the inclusion of environmental consequences in project appraisal. It also led to a national and global concern about a more systematic study of environmental issues: their determinants and consequences including those of population dynamics. Also emphasized is the role of governments and international agencies in the wide dissemination of information about environmental consequences, especially at the local level.

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[6] In 1991, in an interview on the United States National Broadcasting Radio, Milton Friedman stated that democratic participation often leads to more privileges for labor unions and to more demands for elaborate systems of social security that distort market behavior. Such distortion will eventually lead to inefficient resources allocation and loss of total welfare. It is the rights of the market, Friedman argued, rather than democratic participation that should be guarded.

EMPIRICAL ILLUSTRATIONS

In this section, we examine the links between population change and two basic renewable resources, namely, water and cropland. The purpose is to elucidate the mechanisms that may trigger conflict and violence. The findings reported in the Homer-Dixon, Boutwell, Rathjens (1993) study is an excellent base for the present discussion. Their report is based on findings from a team of 30 researchers whom they assembled to examine a set of specific cases relating environmental change to violent conflict. They focused on the two renewable resources of interest, water and cropland, to the present analysis. Population was an important variable in their analyses. Their general conclusions are illustrative

> *Evidence gathered points to a disturbing conclusion: scarcities of renewable resources are already contributing to violent conflicts in many parts of the developing world. These conflicts may foreshadow a surge of similar violence in coming decades, particularly in poor countries where shortages of water, forests and, especially, fertile land,* coupled with rapidly expanding populations, already cause hardship (Homer-Dixon, Boutwell, Rathjens 1993: 38).

We start with the HBR definition of resource scarcity. Scarcity is produced in three different ways. *First,* it may result from degrading or consuming the resource at a rate faster than its renewal rate. *Second,* where the resource per capita declines as a result of a high rate of population growth. *Third,* where a change in the distribution of a resource results in concentrating supply in the hands of a few, subjecting the rest to extreme scarcity. We may also add, as a *fourth* dimension, ecological change that occurs independent of human action.

Their first example of cropland scarcity refers understandably to the case of Bangladesh. Given the built-in population momentum mentioned earlier, Bangladesh's population of 120 million is expected to double during the next 30 years. With an average density that is almost three times higher (2.75) than that of the neighboring Indian state of Assam, the seeds of conflict were already planted. Legal and illegal migration from Bangladesh to India have been a source of increasing conflict between the two countries and have created ethnic and religious tension and violence

> *In the village of Nellie, Lalung tribespeople massacred nearly 1700 Bengalis in one five-hour rampage* (Homer-Dixon, Boutwell, Rathjens 1993: 40).

At destination, migration creates a shift in the balance of political and economic power that is violently resisted by the original power structure. It essentially creates an explosive situation that could be triggered by unexpected and, often, minor incidences.

This case of cropland scarcity and high rates of population growth that exceed the effective supply of a vital renewable resource illustrates some important points related to population dynamics and conflict. The momentum of population growth that has been built through generations of high fertility does not disappear suddenly. Under conditions of increased resource scarcity, it triggers spatial movements that interact with ethnic, religious, and racial origin to keep tension and violence alive through future generations. Increased density, coupled with a subsistence economy, leaves little room for social or political adaptability. Environmental shocks, even minor ones, could easily trigger a chain of events that leads to forced migration and violent conflict.

Almost all areas of the world are experiencing a decline in cropland per person. The trend will continue well into the 21st century. This is mainly a result of the *population* momentum built into the populations of the developing countries. It is also a result of *a very low supply response* of available cropland. Asia, with the highest human concentration, has the lowest per person availability of cropland, about 0.15 hectare per person in 1989 that is expected to decline to 0.1 by 2025. In Africa, cropland per person was 0.3 in 1989 but is expected to decline to 0.1 by 2025. These trends in cropland availability per person, if not compensated by innovations in land use, will be a serious source of conflict through the next century.

The second case of the effects of cropland, water availability, and population dynamics on conflict, mentioned in the HBR study, relates to the violence that erupted between Senegal and Mauritania. The violence seems to have been triggered by a complicated set of factors including a cooperative regional project: the building of the Manantali Dam on the Bafing River and the Diama salt-intrusion barrage. Population growth in this part of Africa exceeds two percent per year. With a very young age structure, the prospect for future increase is guaranteed for many decades to come. According to a Food and Agriculture Organization report, quoted in HBR, the three countries of Mali, Mauritania, and Senegal were included in the critical list of countries whose croplands cannot support current or projected populations without a large increase in the use of fertilizer and water for irrigation. More intensive cultivation of existing cropland is deemed impossible without increased water resources. The situation was considered a matter of survival. Accordingly, the three countries agreed to develop these joint irrigation projects with the blessing and financial support of the international community.

The project was considered by the international development agencies as a model for regional cooperation in the sub-Saharan region of Africa. However, the combination of the structure of political power, unequal wealth distribution, and ethnic composition in these countries produced unexpected outcomes. The announcement that the dams would be built created expectations of rising land values. In Mauritania, the elite, mainly Moors, used their power to take advantage of the situation. They succeeded in changing the legislation governing land ownership in their favor. The change in legislation effectively deprived a large segment of the population of cropland ownership. These were mainly nonMoors. Ethnic violence erupted when, in 1989, some Senegalese farmers were killed in Mauritania. This triggered a chain of events that led to ethnic conflict and violence in the two neighboring countries. The events included confiscation of properties, expulsions and forced migration of nationals, and, finally, violence. These events were further exacerbated by attempts on the part of the privileged groups to exploit the situation further and seize even more. The two countries were almost on the brink of war.

The forces of population dynamics, especially high growth rates and uneven distribution of wealth and political power, have created an increased scarcity of renewable resource endowments. The attempt to deal with the short-run implications of the situation, by improving the productivity of cropland through vertical technology, required action by the state that implied some difficult decisions regarding the distribution of gains and losses. These difficulties arose mainly from the presence of an unequal distribution of political power that controlled the behavior of the state, and that ran mainly along ethnic lines. On the other hand, long-term solutions that require a reduction of the excessive rates of population growth and a more efficient allocation of scarce resources for sustainable development were not forthcoming. This was the case primarily because of the structure of existing social and political institutions. In the absence of long-run development vision and action, the potential for future conflict can only increase. It is evident, however, that the role of population dynamics in creating conflict depends on the presence of such social and political conditions. Population pressure has clearly accelerated a process that has been dormant for some time. It also reduced the system's ability to *adapt* effectively in the face of change.

Water is the second renewable resource that interacts with population dynamics to produce the potential for conflict and violence. The example from the Middle East mentioned in HBR illustrates how national and international forces combine with resource scarcity and population dynamics to produce conflict and violence. The Middle East is an area where the situation of water scarcity is critical, and could only get worse in the future. The potential for political discord is significant. In the Middle East, water scarcity is combined with some of the highest rates of population growth in the world through high rates of natural population increase or excessive net immigration.[7] The region is also characterized by increasing cropland scarcity, unequal distribution of resource endowments, imbalances in the distribution of military power, and the presence of unstable political regimes. This is a situation where a minor incident could trigger a chain of events that would lead to unpredictable outcomes. The case of Israel and the occupied territories discussed by HBR illustrates these dynamics. Indeed, concerns over access to water resources preceded the 1967 Arab–Israeli war and contributed to earlier tensions. The 1967 war, however, gave Israel control over most of the Jordan Basin's water resources. This control and the pattern of its utilization created nonsustainable imbalances between the supply and demand for water among the population groups living around the Jordan Basin that include those of Israel, Jordan, Lebanon, Palestine, and Syria.

The situation is best illustrated by Miriam R Lowi of Princeton University. She estimates that

> *The average amount of renewable fresh water available annually to Israel is about 1950 million cubic meters (mcm). Sixty percent comes from ground water, the rest from the river flow, floodwater and wastewater recycling. Current Israel demand – including that of settlements in the occupied territories and the Golan Heights – is about 2200 mcm. The annual deficit of about 200 mcm is met by over-pumping aquifers. As a result the water table in some parts of Israel and the West Bank has been dropping significantly. Two of the three aquifers on which Israel depends lie for the most part under the West Bank, although their water drains into Israel. Thus, nearly 40 percent of the groundwater Israel uses originates in occupied territories* (Homer-Dixon, Boutwell, Rathjens 1993: 44).

The Israeli government introduced strict measures to limit the use of water resources in the West Bank. These measures were not equitable. According to the HBR study, the distribution of water resources was as follows

> *Of the 650 mcm of all forms of water annually available there, Arabs are allowed to use only 125 mcm. Israel restricts the number of wells Arabs can drill in the territory. On a per capita basis, Jewish settlers consume about four times as much water as Arabs. Arabs are not permitted to drill new wells for agricultural purposes, although Mekorot*

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[7] The present discussion is illustrative of a large and complex subject. In a recent literature review, Watson (1994) lists over 160 studies that deal with the socioeconomic and political aspects of water policies in the Jordan Basin region alone.

> *(the Israeli water company) has drilled more than 30 for settlers* (Homer-Dixon, Boutwell, Rathjens 1993: 44–45).

Such severe inequalities in access to such a vital renewable resource could be a serious source of conflict and violence. However, given the comparative advantage of the Israeli military power, water shortages may create more intracountry conflict than intercountry 'water wars'. The situation is unstable and could destabilize further through the process of *population growth and its built-in momentum.* For example, because of the agricultural water policy, most of the Arab Palestinian population was forced to quit agriculture. They either became unemployed or sought jobs in Israel. The Palestinian population has a very young age structure. As a result, the rate of growth of population and the labor force will continue to increase at high rates at least for half a century, given reasonable assumptions about the future path of fertility. Nonagricultural labor absorption must accommodate the natural increase in the labor force as well as the forced exodus from the agricultural sector. If not, the excess labor supply will be a source of conflict either as emigrants or unemployed civilians.

The current peace process that is being initiated in the region includes an attempt to reach agreements on water use among all parties concerned. Such agreements should reduce short-term tensions. Conflict, however, seems to be built into long-term, high rates of population growth, their momentum, and the implied increase in water demand. It must be emphasized that future demand for water does not depend only on population growth. It depends equally on improvements in living standards and on the technology used in agricultural and industrial production. These latter factors could also reduce the effective water supply by degrading water quality through increased waste and pollution. Commoner (1991), for example, has found that the effect of technology on environmental degradation far exceeds that of population and per capita income growth rates combined. Commoner further concludes that direct control of the sources of pollutants has been more efficient in containing pollution levels than policies using indirect methods that rely primarily on market forces.

CONCLUSIONS

In this paper, the relation between population dynamics and conflict has been examined. The conclusions reached are based on conceptual analyses and empirical observations. The main conclusion of the paper is that population change has significant effects on social and political conflict; however, these effects are not direct. They exert their impact through other proximate factors such as increased scarcity of renewable resources, reduced economic productivity, migration expulsion, or the weakening of the state authority. Furthermore, the net effect of population change on conflict is not easy to assess. The effect of population change depends on the levels of other indirect factors such as inequality and the quantity and quality of existing resources.

An important corollary is that population change could create conditions that reduce the *adaptive capacity* of society. That last effect depends, among other things, on the *structure* of the social and political system. That *structure* includes, for example, the degree of society's ethnic and cultural homogeneity and the degree of equity in the distribution of income, opportunities, and political power. Furthermore, the effect of population change on the adaptive capacity of society depends on the types of political and socioeconomic institutions. The probability that conflict would be reduced is greater if such institutions were able to introduce necessary changes and, in the meantime, were able themselves to adjust to accommodate such changes.

The paper also identified various mechanisms through which population change affects conflict. These are long- and short-term effects. It was emphasized that the long-term effects of population dynamics on conflict are the most serious. This is the case because the impact of long-term trends is not sudden but creeps in slowly. However, once the trend takes hold through the presence of a population momentum, it becomes difficult to contain or reverse. This argument is not novel. A similar example was given by Goldstone (1986), in which he argues that the factors that led to the English Revolution were

> *...driven by the underlying force of population growth in the preceding century and a half...[Which] created a synergistic stress that caused the breakdown of the state power* (Goldstone 1986: 257–322).[8]

The long-term effects exert themselves through the influence of the shape of the age structure on the growth rates of population and the labor force. This built-in momentum creates conditions for system vulnerability, especially in poor countries with scarce renewable resources. It must be emphasized, however, that the built-in momentum of labor force growth is not necessarily a negative influence. It could be a source of future conflict, or alternatively, a facilitator for development. Whether society moves towards a costly conflict or towards sustainable development will depend on the success of its development efforts and how equitable its outcome is. A continuation of high rates of population and labor force growth will generate *conditions* for violent conflict. Countries that postpone their fertility transitions will only increase the size of the momentum, increase its impact on system vulnerability, and reduce the potential for sustainable development.

[8] This reference was brought to my attention by Carol Underwood of the Johns Hopkins University.

The short-term effects are mainly those of population movements. Population movements are initiated by the long-term interplay of population growth and resource scarcity. Large movements occur, however, as a result of sudden shocks when the society reaches a state of system vulnerability. Population movements are equally sensitive to nondemographic forces. Relative deprivation as a result of economic inequalities within countries or across neighboring countries could result in large and sometimes unwelcome population movements leading to expulsion. Conflict is more likely to occur in situations that include ethnic, religious, or racial minorities, and where inequalities are high and are identified with these social groups.

A brief summary of the empirical findings are listed below.

1. In countries with extreme poverty and high cropland density, population movements may cross international boundaries. Serious conflict arises, especially in the presence of ethnic rivalry. This was the case of Bangladesh and Assam. The case also represents the situation of many sub-Saharan African countries.
2. In countries with severe economic and political inequalities, conflict could arise even as the state attempts to remedy the negative consequences of long-term population growth. Such conflict could cross international boundaries. This was the case of Mauritania and Senegal. Population growth created resource scarcity. The elite who had political power were able to extract privileges. A process of costly ethnic violence erupted. The resolution of that short-term conflict did not deal with the basic underlying causes. There has been no serious effort to deal with the excessive rates of population growth. Neither is the inequity of the political system resolved, that reduced the ability of the state to deal efficiently and equitably with such situations. The potential for future violence is very much alive.
3. Countries with joint claims on a critical renewable resource, such as water in the Jordan Basin, impose solutions based on relative military power. In the aforementioned case, these solutions did not give adequate regard to the needs of large segments of the population. When solutions are imposed based on ethnic or religious lines, the outcome is an unstable system that serves as a breeding ground for conflict. The potential for future conflict increases when the populations concerned have a high growth momentum. The need for international mediation becomes essential. This is the Middle East case.

In our discussion of the Middle Eastern region, we only emphasized the potential role of population dynamics in creating conflict in the presence of renewable resource scarcities. We did not dwell on the role of oil politics and the associated international labor migration in the region, especially in the Gulf countries (Sirageldin 1992). There seems to be a potential misreading of the directions of future events in the region that requires comments. The Economic and Social Commission of Western Asia (ESCWA), for example, predicted that the nonnational labor force in the Gulf countries will continue to grow at the rate of three percent a year through the present century (ESCWA 1992). Such scenarios have been used to predict future economic trends in the region, including external financial flows (e.g., Diwan, Squire, Underwood 1993). The analyses might be valid in the immediate term. As the discussion of the present paper illustrates, 'longer-term trends and prospects' must deal simultaneously with the interaction of population momentum and resource scarcity, and the ability of the social and political structure to accommodate these fundamental changes. The economic and social consequences of the built-in population momentum in both the labor receiving and sending countries must be considered in projecting future flows. In a recent comparative analysis of the political economy of Egypt and Turkey during the period 1950–1985, Hansen (1991: xv) shows convincingly that

> *...development in both countries has been too complex to permit simplistic inference and conclusions about causes and effect of poverty, equity, and growth.*

However, Hansen finds some significant differences between the two countries that explain observed differences in the path of their agricultural development. Agriculture grew in Turkey, but not in Egypt during the analysis period, mainly because Turkey was able to expand the extensive margin of land until about 1960, whereas Egypt had reached this point by 1900. The importance of relating the growth momentum of the labor force to resource scarcities needs no emphasis. However, that momentum seems underutilized in the Diwan, Squire, Underwood (1993) analysis of trends and consequences of migration flows in the region. To illustrate, the growth of the native labor force in Saudi Arabia and other Gulf countries is about 3.5% per year. Due to the built-in population momentum, this rate will continue to increase for the next 40 years at least. The result is a fourfold increase in the size of the national labor force in these countries. The evaluation of such a prospect should be the basis for the analysis of longer-term trends and consequences of migration flows. The *potential* for future conflict is already built into the present sociodemographic system. Present analyses and policies should anticipate the consequences of such built-in demographic momentum, especially as it interacts with the resource base. Goldstone's (1986) analysis is illustrative of such historic consequences.

In summary, the discussion indicates that the effect of population change on violence depends on the existing socioeconomic and political structure. However, the strength and ability of the state to manage also depends on that same structure. Most of the literature on conflict focuses on the short-term manifestation of population change, such as population movement. Forecasting the future, however, requires a careful look into the shape of the age structure and long-term population dynamics. Almost all of the populations of the developing world have a young age structure with a high momentum for growth, especially its labor force. Disparities between the future supply and demand for labor could generate processes leading to serious conflict. However, attempts to increase the demand for labor could be self-defeating if they lead to overconsumption, severe socioeconomic disparities, or excessive population growth relative to resource formation. The outcome of such efforts is resource scarcity leading to a state of system vulnerability where reaction to immediate crises consumes the bulk of government concerns and resources.

National and international agencies should focus on long-term strategies that promote efficient and equitable development, and that seriously reduce fertility. This concern with long-term developmental direction and vision is most needed but least evident when society reaches a state of system vulnerability. This is illustrated in the context of the population dynamics' basis for a sustainable agricultural transformation in Egypt as follows

> *The problem is that in Egypt the short-term issues (crises) have taken precedence. The success of the policies adopted is a matter of survival. Indeed, all governments are concerned about balancing political stability, equity, and efficient utilization of resources. However, sustainability is an issue of intergenerational equity, and* attempting to buy political stability today at the expense of instability tomorrow is not a sustainable strategy (Sirageldin 1993: 228).

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POPULATION, DEVELOPMENT, AND GLOBAL WARMING: THE INTERNATIONAL INSTITUTIONAL CHALLENGES AHEAD

Frederick A B Meyerson[1]

INTRODUCTION

There is growing scientific agreement that human activity is causing a significant warming of the global climate, primarily through carbon emissions from the combustion of fossil fuels. The Intergovernmental Panel on Climate Change (IPCC), a UN sponsored group of 1000 scientists and reviewers, now predicts a global temperature rise of 1–3.5 °C by the year 2100, with major potential effects on sea level, precipitation patterns, weather, agriculture, and biodiversity (IPCC 1995). Scientists, governments, and international institutions have recognized the need to minimize the level of global warming, through the 1992 United Nations Framework Convention on Climate Change (or the Rio Treaty) and unilateral measures within a few countries. Nonetheless, the pace of carbon emissions has continued virtually unabated since the Rio Earth Summit. Human population increases continue to drive economic growth, energy use, and carbon emissions.

The voluntary limits of the Rio Treaty currently apply only to developed countries. As of 1996, it seems very unlikely that the target of reducing carbon dioxide (CO_2) to 1990 levels in the developed countries by the year 2000 will be achieved. At the same time, fossil fuel use and resultant CO_2 releases have been increasing dramatically in the developing world. In 1995, total CO_2 emissions of the western industrialized countries roughly equalled those of the developing world and the former eastern bloc nations combined, but the relative share of the developing world is projected to increase substantially. Looking into the 21st century, it is apparent that the level of carbon emissions

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and global warming will be a function of the population and development trajectories of a wide group of countries.

Multilateral mechanisms such as the Rio Treaty should, therefore, be given more teeth and applied evenly to all sources of carbon emissions. In addition, a globally determined but nationally imposed carbon tax should be adopted, which would internalize the costs of carbon emissions and create strong economic incentives for maximum energy efficiency. To be equitable and effective, a global carbon tax should be progressive, based on national per capita carbon emissions. This would fairly place a heavier burden on those countries contributing the most to global warming.

International trade agreements could also be redesigned to support universal and equitable application of a carbon tax. Where possible, these measures should be structured in ways that allow the maximum use of free market forces and create strong national and international incentives for population stabilization and sustainable development.

Where the term 'carbon emissions' is used in this paper, it refers to all sources of carbon. However, this paper will focus primarily on fossil fuel emissions, with the recognition that deforestation and changes in land use are also significant anthropogenic contributions to global carbon emissions. It will not deal extensively with chlorofluorocarbons (CFCs), which are now regulated by the Montreal Protocol.

THE GLOBAL WARMING PROGNOSIS

In the fall of 1995, IPCC released a report prepared by a team of 1000 scientists and reviewers, which concluded that 'the balance of evidence suggests that there is a discernible human influence on global climate' (Kerr 1995a). The new IPCC climate model now incorporates both rises in greenhouse gases and the countervailing 'aerosol' particulate cooling effect, a significant advance from earlier models (IPCC 1995; IPCC 1990a; Kerr 1995c; Bolin 1994). Assuming the 'best estimate' value of climate sensitivity and a mid-range emission scenario, the model projects an increase in the global mean surface temperature of 2 °C from 1990–2100, with a potential range of 1–3.5 °C of warming by 2100 (IPCC 1995). The global temperature has already increased by about 0.5 degrees since the late 19th century, according to the IPCC and several other scientific groups (MacCracken 1995; Kerr 1995b; 1996).

In all IPCC scenarios, the rate of warming over the next century would most likely be higher than that was seen in the last 10 000 years (IPCC 1995). Due to the thermal inertia of the oceans, global temperature would continue to rise substantially after the year 2100, even if concentrations of greenhouse gases were stabilized by 2100. As a result of the thermal expansion of the oceans and the melting of glaciers and ice-sheets, the IPCC 'best estimate' model projects a rise in sea level of about half a meter by 2100, with a range of 15–95 cm, given all combinations of emissions and climate sensitivity (IPCC 1995).

A 1 m sea level rise would flood 17% of the total land area of Bangladesh, 12–15% of the arable land in Egypt, and major river deltas in the US, China, Pakistan, Brazil, Argentina, Nigeria, and other countries. Many island countries would suffer severe losses of agricultural and residential land (IPCC 1990b). Other potential impacts include increased flooding, coastal erosion, and salinization of coastal cropland and aquifers (Titus 1989). A net global forest loss of 3.7% in biomass (5.8% in area) may occur because of temperature and precipitation changes, with even larger losses during the transition (Sedjo, Solomon 1989).

Species extinction may potentially be the gravest loss due to global warming, although very difficult to quantify (EPA 1989; Cline 1992a). Habitats, ranges, and community relationships of plants and animals could be altered dramatically in a few decades, beyond the ability of many species to adapt or migrate. These effects would be exacerbated by anthropogenic barriers and fragmentation of habitat. In marine zones, ocean warming, bleaching of coral reefs, inundation of estuaries, and alteration of ocean currents are also expected to cause substantial extinction (Titus 1989; Norse 1996).

Predictions for economic losses due to global warming vary widely but could be of the order of five percent per year of gross domestic product (GDP) (Winters 1992), though it is virtually impossible to calculate the complex set of indirect effects that climate change would have on national economies and the world market. Potential annual agricultural losses have been estimated at roughly seven percent of world production, or $40 billion (Cline 1992b). In the US alone, the annual cost of forest loss and sea level rise could be $4 billion and $10.6 billion, respectively (Cline 1992b). Countries with heavily populated or agriculturally developed coastlines would suffer the most, together with nations and people that depend on marginal land, where small differences in temperature or precipitation may greatly affect agricultural fertility (Repetto 1994; IPCC 1990b). Agricultural effects may be of greater concern as global per capita grain production has been rather flat or has fallen slightly over the last two decades (USDA 1993; Brown, Kane, Roodman 1994).

The adverse effects of global warming are predicted to affect all parts of the world (Kerr 1995a). Regional impacts will probably vary, and agricultural prospects may even improve in certain locations, but it is expected that most countries, whether industrialized or developing, would experience serious human health, economic, social, and environmental problems and dislocations. The ranges of vector-borne diseases, such as malaria, yellow fever, and dengue fever, are likely to increase (IPCC 1995). While effects may be roughly evenly spread on a global basis, the capacity to respond is not. Countries with high population densities and/or less developed economies may be more poorly equipped to navigate warming effects such as rising sea level, shifting agricultural productivity, and variances in amounts, distribution, and intensity of precipitation (IPCC 1995; Kerr 1995a; Keyfitz 1992).

There is a long time lag between anthropogenic emissions and actual global warming, and the effects are not considered to be reversible in any politically relevant time scale. Greenhouse gases added to the atmosphere today will, therefore, continue to have a warming effect on the global climate for more than a century and probably several hundred years (Houghton, Callander, Varney 1992). Therefore, emissions policy over the next few decades will have an impact on several future generations as well.

GREENHOUSE GAS SOURCES: PAST, PRESENT, AND FUTURE

Several gases contribute to the global warming process, including CO_2, methane (CH_4), CFCs, and nitrous oxide (N_2O). IPCC has calculated that the contributions to climate change of these gases during the 1980s were as follows: CO_2 - 56%, CFCs - 24%, CH_4 - 15%, and N_2O - 5% (IPCC 1991).

From 1980 to 1990, the estimated relative contributions of greenhouse gases from human activities were as follows: energy - 46%, CFCs - 24%, forestry - 18%, agriculture - 9%, and cement manufacturing and landfills - 3% (IPCC 1991). As mentioned in the introduction, this paper focuses primarily on the energy (fossil fuels) sector, though reduction solutions could and should be applied to all carbon emission sources. On a per capita basis, carbon emissions in 1990 ranged from a high of 33.11 tons (United Arab Emirates) to only 0.03 (Nepal), a difference of more than three orders of magnitude (Engelman 1994). The global per capita average in 1990 was about 4.2 tons.

Global carbon emissions from fossil fuel burning alone have increased from about 540 million tons in 1900 to 1.62 billion tons in 1950 and 5.904 billion tons in 1993 (Brown, Kane, Roodman 1994). Combustion of oil accounts for more than 40% of fossil fuel carbon emissions, followed by coal (approximately 40%) and natural gas (less than 20%) (Brown, Kane, Roodman 1994; Marland 1983).

The developed world is, and has been, the primary contributor of carbon emissions in the present and in the past century. The US is by far the largest contributor, emitting nearly 1.4 billion tons in 1992 (Brown, Kane, Roodman 1994). Western Europe, 'Centrally Planned Europe', and the Organization for Economic Cooperation and Development - Pacific (OECD Pacific) are also major contributors (IPCC 1991). In 1995, total CO_2 emissions of the western industrialized countries roughly equalled those of the developing world and the former eastern bloc nations combined. However, emissions are growing at a much faster rate in the developing world, and particularly in the rapidly industrializing Asian countries. For instance, in 1992, emissions in China, India, and South Korea grew by 7, 17, and 28%, respectively (Brown, Kane, Roodman 1994).

China will almost certainly become the largest source of carbon emissions early in the 21st century (Lii 1996; Brown, Kane, Roodman 1994). At present economic and energy use growth rates, China will double its share of global carbon emissions from 11% in 1990 to 22% in 2100 (Cline 1992a). China's economic growth over the last fifteen years has averaged 9.4% per year (Esty, Mendelsohn 1995). The number of motor vehicles increased from 1.6 million to 18.8 million from 1980 to 1992, and new car sales are expected to rise by 30% in the next year alone (Esty, Mendelsohn 1995; Tunali 1996). Similar extremely rapid growth of car sales and gasoline use is occurring in Thailand, South Korea, India, Mexico, Brazil, and other countries (Tunali 1996).

The energy future of China also depends heavily on coal – the fossil fuel with the highest carbon emissions per unit of energy derived. China is already the world's largest producer and consumer of coal, burning more than one billion tons in 1993. Estimates suggest that China will consume 2.7–3 billion tons of coal by the year 2020, making China the world's largest source of carbon emissions at 1.7–1.9 billion tons, exceeding the US estimate of 1.56 billion tons for 2020 (Esty, Mendelsohn 1995). India, the world's second most populous country, is also expected to rely heavily on its coal reserves in the future.

On a global scale, the relative share of carbon emissions between industrialized (including former eastern bloc) and developing nations is predicted to shift from 74% (industrialized)/26% (developing) in 1985 to 68%/32% in 2000 and 56%/44% in 2025 (WRI 1994).

POPULATION AND DEVELOPMENT TRAJECTORIES: PAST AND FUTURE

The rise in carbon emissions is closely linked with both population increases and economic development. Between 1950 and 1993, world population increased from about 2.5 to 5.5 billion, an increase of 120% (WRI 1994). Over the same time period, the global economy expanded from 3.8 to 19.3 trillion (1987) dollars, an increase of 408%, and carbon emissions from fossil fuels increased from 1.62 to 5.904 billion tons, an increase of 264% (WRI 1994). Therefore, in rough terms, global carbon emissions between 1950 and 1990 expanded at a rate about twice that of population, and at a slower rate than economic growth.

More recently, since 1970, CO_2 emissions have expanded at a rate approximately equivalent to population growth (Engelman 1994). The only brief pauses in annual global carbon emissions have coincided almost exactly with the widespread recessions of the early 1980s and 1990s, and the oil crisis of the middle 1970s (Brown, Lessen, Kane 1995)

New technology and gains in energy efficiency have reduced, and will continue to reduce, carbon emissions from fossil fuel combustion per unit of usable energy derived, but there are limits to these reductions. On the other hand, as oil deposits run out, a global increase in coal consumption is likely, which will produce higher carbon emissions (Gilland 1995). Ultimately, the combustion of every carbon-based fuel necessarily releases CO_2 as a by-product, and the level of use of fossil fuels is closely associated with development or 'affluence', both on an individual and on a country-by-country scale.

Human population is expected to increase to 8.3 billion by 2025 and to 9.8 billion by 2050, according to the UN medium projection (UN 1994). Unless the global economy is successful in moving completely away from fossil fuels, which is highly unlikely in any time period relevant to climate change, population growth will be a major driving force behind increases in greenhouse gas emissions.

Borrowing and modifying the Ehrlich and Holdren/Commoner $I = P \times A \times T$ equation, carbon emissions from fossil fuels can be thought of as a function of the same factors (Ehrlich, Holdren 1971; Commoner 1972; Ehrlich, Ehrlich 1990).

$$\text{Carbon emissions (C)} = P \times A \times T$$

where P = human population, A = affluence, expressed here as the amount of energy used per capita, and T = technology, expressed here as the amount of carbon emissions per unit of energy. Note that the technology factor can be affected through changes in fuel efficiency or by substitution of higher, lower, or non-carbon emitting energy sources.

The most effective carbon emission reduction policy would address all three factors – population, the level of energy use, and the amount of carbon emissions produced per unit of useful energy.

CURRENT CLIMATE CHANGE AGREEMENTS

At the Rio Earth Summit in 1992, the Framework Convention on Climate Change (the FCCC or the Rio Treaty) was signed by representatives from most of the nations of the world. Its objective was

> *...to achieve...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate...within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure food production is not*

> *threatened, and to enable economic development to proceed in a sustainable manner* (FCCC 1992).

It further advises a precautionary principle, that

> *...(w)here there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing (climate change mitigation) measures* (FCCC 1992).

In the Rio treaty, the developed countries also agree to attempt to reduce carbon emissions to 1990 levels by the year 2000.

While its language is quite bold, the effect to date of the Rio treaty has arguably been virtually zero. The US, the European Union, and Canada have admitted that they will not reach the voluntary emission stabilization target for developed countries for the year 2000, given current trends (*The Economist* 1995a). Sweden, Finland, and the Netherlands have unilaterally adopted carbon taxes, ranging from $1.50 to $62 per ton (Poterba 1992), but it is not clear that this will result in reaching the stabilization target for those countries. The UK and Germany are probably the only countries which will hold emissions to 1990 levels, because of the shutdown of coal-burning industries in eastern Germany after unification and the substitution of the North Sea oil for coal in Britain. Otherwise, emissions in 2000 of the rest of the developed country Rio signatories are projected to exceed 1990 levels by 5–20%.

In 1995, the Conference of the Parties (COP) of the FCCC (or the Rio Treaty) met and produced a document known as the Berlin Mandate. It concluded, not surprisingly, that the commitments of the developed nations to reduce their level of emissions were inadequate (Blaustein 1995). An agreement was also reached to 'set quantified limitation and reduction objectives within a specified timeframe, such as 2005, 2010, and 2020' for the developed countries (FCCC 1995).

Under the original 1992 Rio Treaty, developing countries were requested only to develop and make available 'national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol (i.e., CFCs)' and to formulate 'programs containing measures to mitigate (and adapt to) climate change' (FCCC 1992). Effectively, no action is required, or even strongly suggested, of developing countries beyond data compilation. The 1995 Berlin Mandate reaffirms this lack of commitment on the part of the developing countries, although it does institute a voluntary pilot program for activities described as 'activities implemented jointly' between developed and developing countries to reduce carbon emissions, or 'joint implementation' (FCCC 1995; Esty 1994a). The net practical result of the Rio treaty on carbon emissions from either the developed or developing countries thus far seems to have been a continuation of business-as-usual. In the ongoing negotiations, countries have organized themselves into predictable interest groups, such as the oil-producing nations, which generally oppose policies that might lead to lower consumption. However, the parties will meet again in late 1996 to discuss further possible steps, including firm quotas and tradeable permits (Blaustein 1995).

Short-term political issues like jobs, economic stimulation, and tax reduction have overshadowed climate change in national politics in the developed countries, and developing countries have not yet been required to act. Uncertainty among climate scientists has also been an excuse for inaction (*The Economist* 1995b). In the US, currently the largest producer of carbon emissions, there seems to be little political will to raise fuel prices through additional taxes or to mandate or otherwise promote increased fuel efficiency. Gasoline prices remain, at real levels, only half of what they were 15 years ago, and one-third or less of what they are in most other countries, creating no economic incentive for efficient use.

Despite available technology, the fuel efficiency of the US vehicle fleet is stagnant. In 1980, roughly 80% of Americans drove cars and 20% drove more fuel-consumptive 'light trucks', a category which includes pickups, vans, and sport utility vehicles (Salpukas 1996). In 1995, the share of light trucks had jumped to 43%, with large, low-gas mileage pickups showing the largest gains (Cobb 1996). The largest selling vehicle, car or truck, in the US for the last 14 years has been the Ford F-150, which operates at an abysmal 13–17 miles per gallon (Schuon 1996). The Clean Air Act contains much less stringent fuel efficiency standards for trucks, vans, and pickups than cars, an unnecessary loophole that has effectively more than doubled in size since 1980 and apparently remains open for purely political reasons. This loophole has, in fact, created an incentive for both consumers and car manufacturers to gravitate towards the high-powered, low-efficiency truck market.

The abandonment of the 55 mile per hour speed limit by the Federal Government in all but a handful of the US states has further increased fuel consumption. A consumer group recently calculated that a car loses 18% of its gas mileage when its speed increases from 55 to 65 mph, and 33% if its speed increases from 55 to 75 mph (Salpukas 1996). The net result of these factors is that gasoline consumption in the US has increased at an average annual rate of 1.7% since 1992 and is expected to rise by 2% or more per year for the next five years (Salpukas 1996). This increase, it would appear, is primarily driven by low gasoline prices, higher highway speeds, and a fleet of vehicles increasingly dominated by trucks and sport utility vehicles.

In other words, the increase of fuel consumption and carbon emissions in the US is the result of a political rather than a technological failure. This is unfortunate since the US will have to be a leader in any global carbon emission reduction plan, both because it is the largest source and because it is doubtful that many other countries will follow suit without the US leading the way (Crane 1992). The US government now estimates that it may fail to meet the Rio Treaty emission caps by at least five percent, and even more if climate change funding is cut by the US Congress as expected. To put that failure into perspective, a five percent increase in US 1990-level carbon emissions is equal to 300% of Egypt's total emissions in 1990, 122% of Brazil's emissions, or 36% of India's emissions (derived from Engelman 1994).

As discussed earlier, carbon emissions from the developing world are rising even more rapidly than from the developed world, increasing by more than 50% in the last decade (Brown, Lessen, Kane 1995). Global emissions plateaued briefly in the early 90s, solely because the massive recession in the eastern bloc countries offset the economic boom in parts of the developing world. With the end of the eastern bloc downturn, world emissions are expected to resume their rise. Thus far, there has been little or no redirection of international energy policy to take account of global warming (Boehmer-Christiansen 1994).

In conclusion, while the Rio Treaty was a laudable step, it is clear that much stronger action is necessary to achieve actual carbon emission reductions. The FCCC may be a viable forum for such action, but the past and present strongly suggest that measures such as voluntary carbon emission caps are likely to be ineffective. Moreover, if limits apply only to the developed countries, no net reduction in greenhouse gases is likely, given growth trajectories for the developing world. Within 50 years, China and India, with rapidly expanding economies and large deposits of high carbon emission coal, may dwarf developed world greenhouse gas output. At this point in history, climate change is best addressed globally, or at least multilaterally, among the major carbon emitters, whether developed or developing.

GLOBAL WARMING SOLUTIONS: QUOTAS, TRADEABLE PERMITS, CARBON TAXES, AND INTERNATIONAL TRADE AGREEMENTS

Climate change is a truly global problem, caused by many essential human activities in all countries. Its effects will harm most, or all, people and countries, regardless of the source of the emissions. No individual country is a sufficiently important source of carbon emissions to unilaterally affect the rate of global warming significantly (Poterba 1992). Nor can the problem be accurately characterized as a North/South or a developed *versus* developing countries issue. Past dominance in energy use and carbon emissions on the part of developed countries is being quickly erased by higher population growth and rapid economic and energy use growth in a number of large developing countries.

Therefore, there exists at least the potential for negotiating an equitable global solution. While the 1992 Rio Climate Convention sensibly placed an early focus on carbon emission reduction agreements on the part of the developed world, effective future solutions must obviously include the entire world, and particularly China and other countries with rapidly developing economies who will inevitably be major sources of carbon emissions in the future.

While the substantial future combustion of fossil fuels and the release of carbon emissions is inevitable, the quantity of future emissions could be greatly affected by policy decisions. Six scenarios developed by the IPCC in 1992 project that annual CO_2 emissions could potentially vary from 4.6–35.8 gigatons of carbon (GtC) in the year 2000, depending on levels of population, and economic and energy use growth (Houghton, Callander, Varney 1992). The variance in climatic impacts of these different emission scenarios would be enormous.

In its 1991 report, the IPCC considered several implementation mechanisms, specifically public education and information; technology development and transfer; economic (market) incentives; financial incentives; and legal and institutional mechanisms (IPCC 1991). While all of these may contribute to reduction or limitation of carbon emissions, the following discussion will focus on economic, legal, and institutional mechanisms, particularly tradeable permits and carbon taxes, with specific reference to the interactions between population and development. Under any policy aimed at limiting or reducing global carbon emissions, human population growth will be a significant factor, whether implicitly or explicitly, since total emissions are a function of per capita output multiplied by the number of people.

At least two general approaches are available. The first approach would be to hold each country to a specific cap (i.e., based on a percentage of 1990 emissions) and allow trading of emission 'permits'. Alternatively, the global emission target could be achieved by economic incentives (i.e., carbon taxes), which would involve raising the level of taxation globally until fossil fuel use, etc., are reduced to the desired level of emissions.

TRADEABLE PERMITS

Tradeable permits, or transferable emission rights, would allocate quotas to countries to emit carbon into the atmosphere. The global carbon budget would be set by international agreement, and countries could use their individual quotas or sell them to other countries. Theoretically, the global market would then ensure that the most cost-efficient, carbon emission reduction steps were taken first. This melding of free market principles and environmentalism has been quite successful inside the US (Esty 1994a), but could be more tricky on an international scale.

One serious problem may be how to allocate quotas among countries. If quotas were allocated on the basis of present population size, the industrialized nations would have to pay large fees to developing countries in order to maintain their high current levels of carbon emissions (Carliner 1995). If these quotas were further adjusted for future increases in population, the system would actually create a perverse incentive for high population growth and penalize countries with low, zero, or negative population growth, since a country's carbon emissions quota would be based on its percentage of global population. If, on the other hand, quotas were allocated on the basis of current emissions, as now occurs with some air pollutants such as sulfur dioxide among industries in the US, developing countries with rapidly growing economies and emissions would be faced with huge payments to the industrialized countries in the future.

It is hard to imagine that either of these quota allocation mechanisms would be politically acceptable, because they do not adequately balance current and future levels of development and population, and they might require huge capital flows between countries. The international community is currently debating whether to strengthen the Rio treaty through the use of 'joint implementation', under which developed countries may meet some of their own carbon emission reduction goals by funding emissions-reductions projects in developing countries, where costs may be lower (FCCC 1995). It is still unclear how joint implementation would fit into a truly global carbon emissions scheme.

A variant of the tradeable permit concept is the 'tradeable adsorption option', under which individual energy suppliers would be required to adsorb part of the carbon emitted when the fuel is burned by the customer (Read 1994). It would be designed to encourage energy suppliers to grow trees, pay a third party to grow trees, or pay a third party to install efficient technology to reduce carbon emissions. While retaining the free market aspects of tradeable permits, the tradeable adsorption option would also effectively internalize the cost of carbon emissions into the price of energy, since energy suppliers would pass on the expense of carbon emission reductions to energy purchasers. Its other advantage over a national quota system would be that economic decisions would be made on a more local scale and presumably more efficiently. However, tradeable adsorption options do not actually cap emissions directly, and adsorption may be difficult to monitor, verify, or enforce.

CARBON TAXES

The IPCC has suggested that a tax on fossil fuels, levied in relation to carbon emissions, could be efficient and effective if its level were the same across all countries and it was applied evenly to all fossil fuels (IPCC 1991). Herman Daly (1996) has also suggested a similar proposition, which he refers to as the taxation of 'throughput'. A carbon tax would be levied on the amount of carbon emitted, so that natural gas would be the least taxed per unit of energy output, followed by oil, and coal, the 'dirtiest' fuel, would have the highest tax per unit of energy output (Herber, Raga 1995). The carbon tax, therefore, is designed to equitably internalize the 'external' carbon emission costs into the price of fossil fuels. While most discussions on a carbon tax focus solely on fossil fuels, it may be more appropriate to include all sources, including agriculture, forestry, and industry (Stewart, Wiener 1990).

Poterba (1992) points out that a carbon tax large enough to significantly reduce use and emissions would generate a large amount of revenue, perhaps several percent of an industrialized nation's gross national product (GNP). It is unlikely that any country would be willing to surrender revenues of that magnitude to an international organization. Therefore, domestic carbon taxes, imposed unilaterally at levels agreed to multilaterally, and perhaps regulated or overseen by an international organization, are a more likely scenario. It has also been suggested that part (perhaps 10%) of these taxes could be redistributed to developing countries willing to limit or reverse deforestation losses and increase fossil fuel efficiency (Cline 1992a).

Increased efforts to restrain population growth are also likely to be part of any global bargain. Cline (1992b) estimates that given a mid-21st century population of 10 billion, an annual global carbon budget of 4 GtC, and an intermediate carbon tax of $175 per ton, family planning programs would be worth $1000 to $3000 per birth permanently avoided. Therefore, one appropriate use for carbon tax revenues would be to finance or improve family planning programs and other efforts which directly or indirectly lead to lower population growth.

Within particular countries, it is not necessarily true that a carbon tax and, therefore, higher fossil fuel prices would lead to deleterious economic effects or higher overall taxes. The tax burden could be simply shifted from income, sales, and other taxes to carbon taxes. Higher energy prices would also provide incentives for greater efficiency. The first 20–25% of this efficiency gain might be achieved at zero or negative cost, because the cost of energy efficiency improvements would actually be lower than the increase in fuel prices (Cline 1992a; OTA 1991). Users would also be economically encouraged to substitute lower or zero carbon emission energy sources such as solar power, hydroelectricity, or biomass for existing coal, oil, and gas. Elimination of existing subsidies, which cause inefficient use, could substantially cut global carbon emissions by as much as eight percent (Cline 1992a; WRI 1990).

A frequent objection to fuel taxes, in general, and carbon taxes, in particular, is that they are regressive, because low-income households spend a significantly larger proportion of their income on fossil fuel for heating, cooking, and transportation. A combination of income tax credits, transfers, and other progressive countermeasures can be used to neutralize this effect (Poterba, 1992: 82–83). In addition, carbon tax revenues could be used to subsidize energy efficiency improvements and economic activity with lower carbon emission potential, or to offset otherwise undesirable carbon tax effects. Finally, when negative social, economic, and environmental effects of global warming materialize, the tax revenues can be used to mitigate them.

Tax revenues from a carbon tax large enough to affect consumption would be substantial. For instance, a carbon tax of $100/ton of carbon would produce revenues equivalent to an estimated one to five percent of GDP (Winters 1992). A tax of this magnitude would be very high relative to the price of coal (256% of the estimated producer price) in the year 2000 and lower for natural gas (53%) and oil (49%) (CBO 1990, Cline 1992a). As with tradeable permits, the possibility of huge transfers of capital between countries presents a political barrier to acceptance and implementation of carbon taxes. The specter of a large international organization assessing and divvying carbon taxes on internationally traded fossil fuels is unlikely to play well in national politics in either the developed or developing world.

A more palatable design may be to determine appropriate carbon tax levels globally, but have them assessed by governments of individual countries (Herber, Raga 1995). To make this scheme function equitably, all countries would have to participate in this 'unilateral carbon tax' scheme, since the tax would raise the prices of all commodities which use fossil fuels in some aspect of their production.

To be equitable and most effective, a global carbon tax should be progressive, based on national per capita carbon emissions. This formula would place the heaviest tax burden per unit of carbon emissions on those countries contributing the most to global warming. Thus, countries like the US or Japan, with high per capita carbon emissions, would be required to assess a much higher tax than countries like India or Indonesia, which have low per capita emissions. This sliding scale tax also has the advantage of not drawing a bright line between developed and developing countries, but instead simply assessing greater tax burdens and responsibilities on countries as their per capita consumption rises. It would create a progressive economic incentive for countries, businesses, and individuals to increase fuel efficiency and develop lower carbon emission alternatives.

To prevent any unfair trade advantage on the part of a country not assessing a carbon tax, often described as the 'free rider' effect (Esty 1994a; Piggott, Whalley, Wigle 1992), it might be necessary to add a tariff or a 'border-adjustment', imposed either by an international organization or the importing country, equivalent to the appropriate carbon tax on the 'fuel component' of the product (von Moltke 1993). Some kind of a global environmental organization would be necessary to oversee carbon taxes, carbon emission caps for individual countries, and trade adjustments or sanctions (Esty 1994b). Either a new entity could be created or the functions could be best handled by an existing entity, such as the United Nations Environment Program, the United Nations Development Program, or the World Trade Organization.

Tradeable permits and carbon taxes would have significantly different effects on carbon emission behavior. The first approach, with its emission caps for each country, creates incentives for countries to limit population size and, therefore, retain higher per capita usage limits, unless the caps are readjusted for changes in population. For instance, with a global carbon budget of 4 GtC annually, carbon availability would shrink from 0.7 tons per person today to 0.4 tons per person in the middle of the 21st century, when the world population is expected to be 10 billion (Cline 1992b).

A flat carbon tax would not necessarily create strong enough incentives for wealthier countries and individuals to reduce carbon emissions. The tax burden would fall on all consumers, regardless of their level of development or energy use. A progressive or sliding scale carbon tax, on the other hand, would allow less developed countries to develop tax free or with low carbon taxes, and would place progressively higher burdens on more developed countries with higher per capita emissions.

History strongly suggests that economic incentives like carbon taxes will be the most effective in achieving emission reductions. Since 1960, the only brief pauses in global emission increases have corresponded with large energy price increases or economic downturns. Carbon taxes similarly would affect demand through increased carbon-based energy prices, encouraging individuals and companies to use less energy or to substitute low or zero carbon emission fuels for higher ones. Quotas and tradeable permits may be conceptually viable and could be a part of the equation, but experience to date demonstrates that politics on the international and national scale is likely to derail, delay, or weaken agreement and implementation.

CONCLUSION: EQUITABLY AVERTING THE TRAGEDY OF THE GLOBAL CLIMATE COMMONS

Ideally, a climate stabilization policy will equitably provide incentives for both individuals and nations to reduce their carbon emissions. As long as population continues to grow, however, the per capita emission budget must continue to decline, if global carbon emissions are to remain constant (Engelman 1994). Therefore, energy and climate stabilization policy should also be related to population stabilization to avoid a tragedy of the global climate commons (Goodland, Daly, Kellenberg 1994). Public scientific acknowledgment and explanation of the links between population, consumption, and global warming would be an appropriate start in the current atmosphere, where family planning aid programs are being severely cut in the US and other countries (Crossette 1996).

An effective and efficient strategy to achieve climate stabilization goals may be a globally determined but unilaterally administered carbon tax, assessed on a sliding scale based on national per capita emissions. This system could be combined with specific national caps based on population in a benchmark year. Both the taxes and the caps could be enforced through international trade mechanisms. This kind of scheme would allow the maximum use of free market forces and individual choice to determine how carbon emission reductions are achieved. Wherever possible, people should understand that their personal behavior affects the global environment and climate. The use of national caps will, however, also create a strong incentive for governments to strive for population stabilization so as to retain a higher per capita carbon emission budget.

Such a strategy is by no means a perfect or easy solution. The use of national caps could provide a disincentive for countries to permit net immigration above zero; it could also drive other countries to adopt oppressive means of population control. National caps would likely need to be adjusted with respect to population changes due to migration, or to respond to climate alterations in temperature, precipitation, agriculture, and sea level. Each round of negotiations would be as lengthy and problematic as the current efforts. Precisely because of these inherent practical and political difficulties with national emission caps, carbon taxes are an essential component of climate stabilization policy and probably should be the centerpiece of that policy.

As with many environmental problems, the carbon emissions puzzle involves balancing the rights of the individual against the rights of the human species, the rights of the present generation against those of future generations, and the rights of human beings against those of other species endangered by a changing climate. Because global warming is caused by the individual actions of virtually every person on the earth and will also affect them or their descendants, it requires a global solution. Internalizing the future costs of climate change into the present cost of carbon emissions and simultaneously encouraging nations to stabilize both population and emissions appears to be the most equitable, efficient solution, and can support other important global goals.

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LIFE-STYLE AND TECHNOLOGY: HOW MUCH DIFFERENCE CAN THEY MAKE?[1]

Faye Duchin[2]

MODERN LIFE-STYLES AND TECHNOLOGIES

We ask the question – how many people can the earth support? – out of curiosity about human life on our planet. However, it also reflects the apprehension that there may be unpleasant consequences if critical thresholds exist and are crossed. The repercussions could entail positive feedback between irreversible impoverishment of the natural world and large-scale social distress and violence.

There are more people alive today than in any earlier period and a larger proportion lives in material affluence (by any measure). Contemporary technologies, such as those for extending life or extracting materials from the environment and transforming them, are unprecedented in their power to alter nature and to make existing technologies obsolete. The combination of these forces has had a noticeable impact on water, land, and air, and has expanded the habitat appropriated by humans at the expense of other forms of life.

Such social and environmental pressures are magnified by the global appeal of trying to copy one particular life-style – the affluent way of life pioneered in the urbanized western democracies – which involves an explosion in the volume and variety of goods and services that are produced for sale. Following the apparent failures of socialism and 'third ways', such as those of Gandhi and Nyerere ('self-reliance' in Tanzania), this is now seen as the virtually unique path to progress. The dominance of this model of economic development reflects a massive influence on life-style aspirations along with a transfer of technology from rich to poor countries. It explicitly entails the adoption of social values and institutions developed in market economies by both formerly communist and nonindustrialized agrarian societies. Pressures for entering first the monetized economy and then the global economic system are felt at all levels, from villages to national governments. As an instance of the latter, the World Trade Organization is now hearing proposals to extend its promotion of free trade in goods and services to the liberalization of foreign direct investments.

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The demonstration effect, whereby the dominant technologies, life-styles, institutions, and values of the rich market countries are emulated in other places, is convenient for both the originators and the imitators. For the originators, these ways are familiar and predictable. For the imitators, they seem like a proven formula for modernity and success. The transfer process is accelerating because higher rates of return on investments in faster-growing economies of the developing world attract the profits earned in the developed countries.

The pursuit of what I will call (with apologies to Europe and Japan) American life-styles and technologies is deeply rooted and conveys many benefits. Nonetheless, undesirable, unintended consequences are clearly observable in the form of characteristic social and environmental problems in rapidly industrializing countries (not to mention the characteristic problems of the rich countries themselves), as well as truly global ones. It is against this backdrop of the growing dominance of American life-styles and technologies that we must situate the question: how many people can the earth support?

WHAT ARE THE ALTERNATIVES?

While there are many utopian visions about an egalitarian future, I have never heard it suggested that all the people on the planet could live like affluent Americans. At the other extreme, there are plausible scenarios that most people would consider highly undesirable. One can imagine, for example, the rich living (at least for a while) in 'bubbles of richness' (Gallopin 1993: 10), separated from wretched droves by walls, closed country boundaries, police, and armies, and provided with clean air, water, and other necessities by purification plants of all descriptions. Gated communities, immigration pressures, and bottled water provide a foretaste.

An equally plausible but much more reassuring outlook was offered by the Brundtland Report, *Our Common Future*, a widely cited document drafted by a committee of prominent individuals representing all the corners of the world. In this view, increased affluence based on economic growth is necessary for the rich and the poor alike and can be achieved by adopting clean, modern technologies which simultaneously lower costs and reduce waste and environmental degradation. According to the authors, the political commitment to 'manage and improve' technology and social organization can lead the way to a new era of economic growth and sustainable development (WCED 1987: 8–9).

Even if such outcomes could be reached by the kinds of means discussed in the report, they might be difficult to achieve politically. However, if they are not even physically feasible, the political commitment to them could not succeed. In this case, the commitment would be wrong-headed because it would obstruct the search for other solutions by providing a false sense of security.

My colleagues and I were asked to analyze whether or not the technical means described in the Brundtland Report could achieve the stated objectives. To do this, we made use of a model and database of the world economy, detailed in coverage but of simple structure, that has been implemented with support over the years from the United Nations.[3] We compiled a description of production and consumption in all parts of the world economy, focusing in particular on the use of energy and materials. Methods were developed to describe the present technologies in electric power generation, industrial energy use, the processing and fabrication of metals, construction activities, household uses of energy, and the production of cement, pulp and paper, and motor vehicles. The technical literature provided the basis for this description and for scenarios about specific changes in technology and organization that could be anticipated in different regions over the next several decades. The scenarios follow the Brundtland Report in leaning toward assumptions that are optimistic in terms of increased efficiency and reduced environmental degradation, such as high rates of recycling of materials (Duchin, Lange 1994).

Our results suggest that modern clean technologies and conservation practices can economize substantially on materials and energy and can, on balance, reduce costs of production. However, their ability to reduce pollution relative to today's practices cannot offset the effects of increases in population and material standards of living; the pollutant emissions that we examined in our study all increase over the next several decades. The Brundtland Report was, and still is, important for its portrayal of the scope and interconnection of many social and environmental problems on a global

[3] The World Model system divides the world into 16 interdependent geographic regions, each described in terms of the production and consumption of over 50 goods and services with resource inputs and pollution emissions measured in physical units. The scenarios describe alternative paths over the period through 2020. The methods and results, described in detail in Duchin, Lange (1994), can be contrasted with the rather different approach to global modeling and to the economic and environmental policy described in Nordhaus (1994) which is the basis for the economic analysis of the Intergovernmental Panel on Climate Change.

scale. However, its recommendations do not provide an adequate basis for realistic national and cross-national policies.

Thus, we can expect that over the next several decades our numbers will increase by several billion people and they will live, on average, in an environment that is more rather than less degraded than today. If we hope to prevent such an outcome, we need to envisage much bolder departures from present practices and trends in terms of both life-styles and technologies. The rich countries may need to adopt, and transfer, different kinds of life-styles and technologies that are more benign. They could encourage experimentation in developing countries with approaches outside of the dominant trends by systematically reducing rather than intensifying pressures to copy the 'American' patterns.

These suggestions, however, run counter to some deeply held convictions; that society has one specific objective (or a small number of them) and that there is one uniquely 'optimal' solution for achieving it; that state-of-the-art technologies are more profitable than ones of earlier vintage; that more profitable options will, and should, always be selected over less profitable ones; and that all rational people, when they act on their own account, are consumption maximizers. On closer inspection, of course, each of these convictions is seen to be highly stylized. The fundamental challenge, more fruitful than criticizing these idealized notions individually or jointly, is to describe concrete technological and life-style alternatives that are demonstrably superior in specific contexts. In the area of technology, there is a history of considering alternatives and several new kinds of efforts are under way. However, there is far less experience in describing life-styles in a systematic and concrete way, let alone in conceiving potentially attractive alternatives to mainstream affluent life-styles.

THE RESEARCH CHALLENGE: CONSTRUCTING AND ANALYZING ALTERNATIVE SCENARIOS

There is no definitive answer to the question: how many people can the earth support? It depends on where and how they live and on the state of natural systems. For most of our time on the planet, people lived as hunter-gatherers, but it might well be hard for even a small population to survive in this life-style in the aftermath of a global industrial society (Gowdy 1994). Assuming that the human population will increase and, perhaps, double over the next 50 to 100 years, how could we do better than attempting to follow the prescriptions of the Brundtland Report?

There are a number of approaches to alternative technologies that represent substantial departures from today's so-called best practices. 'Appropriate technology' (Schumacher 1973) is one important strand. Its proponents argue that techniques and tools must be chosen in the context of the social system in which they are employed. In this view, labor-intensive approaches and simple technologies based on local production, whether of traditional design or newly created, are well-suited to the situation in most developing countries. Florman (1981), an engineer who recognizes what he calls the danger of these views, rebuts them on social as well as technical and economic grounds in a way that is incisive but too readily dismissive, in general, of a proposition that needs to be examined in specific contexts. If the idea of appropriateness could replace that of unique solutions, Schumacher could have the following among engineers that will be necessary for the implementation of his ideas.

Industrial ecology (see, e.g., Allenby, Richards 1994) is a new approach to engineering design that is supported by parts of the engineering profession and the manufacturing community. The guiding ideas are a life-cycle perspective and the attempt to 'close the loops' in the use of energy and, especially, materials. Design objectives include not only physical properties and economy, but also durability, recyclability, and disposability. The objectives of industrial ecology have been described in general terms as the decarbonization of the energy system and the dematerialization of production, but the work that has been done to date within this framework focuses mainly on innovations that are cost-saving for manufacturers but relatively modest in their overall impact.

Several scenarios, which would substantially reduce net carbon emissions from combustion, represent large departures from current practices. One is an energy system that operates on photovoltaics and hydrogen fuel (Rogner 1996), and another is the large-scale production of biomass for fuel (Williams 1994). A case has also been made for the widespread use of biomass for industrial materials (Morris, Ahmed 1992). Two ambitious approaches, which have been successfully implemented in many settings by their inventors, are the 'living machines' of John Todd (Todd 1991; Todd, Josephson 1995), ecosystems designed for remediation of polluted bodies of water or for sewage treatment, and 'permaculture', the customized systems of intensive agriculture designed by Bill Mollison (1988). These practical, highly creative lines of thinking and action provide the raw material for building alternative scenarios.

By contrast, practically no systematic work has been done about life-style. Consequently, while any engineer could name dozens of technologies, economists would have difficulty in distinguishing even a few life-styles. The starting point needs to be a classification of household types in a given society according to common patterns of work, leisure, consumption, attitudes, and the values of its members (Duchin 1995). The kind of classification that is needed has been developed not by social scientists but by market researchers who describe American life-styles in terms of several dozen categories, including, for example, Gray Power, Black Enterprise, and Blue-Collar Nursery (PRIZM system, Claritas Corporation; tabulated in Weiss 1988). While the market researchers are interested in niche markets for beers or magazines, our challenge is to define a set of activities for each group of households, or life-style, describe how the activities are carried out, and then develop alternatives. One activity, for example, is recreation, which could involve vacation travel by air, purchase of specialized electronic or sports equipment, or hiking near home. The provision of food can involve eating out, purchase of products that are highly processed and heavily packaged, or a diet of mainly grains, tubers, and vegetables. An analysis of life-styles in terms of activities is directly analogous with a 'process analysis' of industrial production.

This effort needs to combine the systematic, comprehensive, and quantitative coverage of the social accounting tradition among economists (for a review, see Duchin 1996) with the empirical content that can be provided by anthropologists, sociologists, and other social scientists. My colleagues and I are in the early stages of this kind of work in several developing countries (the Dominican Republic, Namibia, and Indonesia). Each society presents unique challenges for even the first step, the classification of households. A number of such studies need to be carried out before generalized concepts and methods can be identified.

As the framework is in such an early stage, I can only hint at what will be involved in describing possible alternatives to today's life-styles. Central themes will, no doubt, be the trade-off between time spent at work and leisure time, and how leisure time is spent. These decisions, in turn, depend upon attitudes toward nature and the existence of public places, such as neighborhood centers for the youth and the elderly. Important decisions related to mobility and the choice of transport are directly dependent on how communities are physically laid out and the convenience of public transport.

On the basis of these kinds of work, one will be able to construct qualitatively new scenarios about life-styles and technology. Then selected scenarios need to be analyzed, such as we have analyzed the scenario implicit in the Brundtland Report, to determine the order of magnitude estimates of their physical implications. For a subset of the scenarios, it will be interesting to proceed further and assess the costs, prices, economic incentives, and regulations that might be associated with them.

Building such scenarios and analyzing them is as much art as science, as much a qualitative as a quantitative challenge, and one that crosses disciplinary borders. In essence, we need to create a set of stories around different kinds of possibilities, like a historian of the future. Hopefully, some of the stories will capture the public imagination, the way protection of the environment did.

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LUNCHEON ADDRESS

Herman Daly[1]

Ladies and Gentlemen. I would like to narrate a true story, which, at least to me, was an enlightenment. This incident took place when I was working in the World Bank in 1991/92. At that time, the World Bank was preparing its *World Development Report,* which, too, dealt with the topic – development and environment. It was the Bank's chance to take the intellectual leadership in the whole area of environment and development and provide significant thought and critical guidance in the field.

I was not on the team that wrote that document, but, being in the Environment Department, I was asked to review successive drafts of that document. I read them carefully and there was, in the first chapter of the draft, a diagram, the caption of which was 'The relation of the economy to the environment, and the diagram under the caption was a little rectangle labeled 'economy'. To the left of the rectangle was an arrow coming into the rectangle, labeled 'inputs' and, on the other side of the rectangle, was an arrow labeled 'outputs', and that was it.

So, I studied the diagram carefully, and wrote my comments: this is a good start, but there really is not any picture here of the environment. Don't we need a larger figure – a rectangle, or even a circle, something which contains the picture that is drawn, which we would label 'the environment'? That way, we would be clear that the relation of the economy to the environment was a relation of a subsystem to a larger system, which supports the subsystem. We could then talk about the depletion of the environment as a result of drawing raw material inputs into the economy; about the pollution of the environment, as a result of throwing wastes out of the economy back into the environment; and about regenerative capacities, assimilative capacities, and the entropic nature of the flow of the resource throughput. We could say a few interesting things about the relation of the economy to the environment.

A revised version of the draft then came back to me several weeks later. It had the same picture again. Only this time it had a large rectangle drawn around a small rectangle, but without any labels – almost like a picture frame – and no change in the text. I commented that this was an advance, but that we would need to label this larger picture, which would otherwise be merely decorative.

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Two or three weeks later, the earlier draft was sent to me, and I eagerly looked for the figure, but the diagram no longer existed. There were no further attempts to draw a picture of the relation of the economy to the environment. Why was it so hard to draw a simple picture of the relation of the economy to the environment?

Several weeks went by. There was a book review and discussion on *Beyond the Limits* at the Smithsonian Institute by Mr Lawrence Summers, then the Chief Economist of the World Bank, under whom this report was ultimately being written. One of the handouts of the session had a little diagram, showing the economy as a subsystem of a larger system, just like the one I had suggested. In the question-and-answer session, I scurried up to the microphone, pointed to the diagram, and asked: do you think that economists should be concerned with the questions of the proper size or scale of the subsystem of the economy relative to the total ecosystem, which sustains and supports it, as in this picture. Before I could finish, I was told that it was not the right way to look at it. Following that, Mr Summers went on to speak of other things. So that was the end of it. However, I continued to mull over it in my mind and thought that if that was not the right way to look at it (which sounded rather peremptory and dismissive), then what would be the right way to look at it?

The right way to look at 'it' is what the great economist Joseph Schumpter called a preanalytic 'vision'. Schumpter says that analysis has to begin somewhere. We don't start from scratch. We have some conceptualization of the nature of the problem we are going to analyze. That is the preanalytic act, which he called 'vision'. So, my preanalytic vision is the economy as a subsystem of a larger system, which sustains the economy. I cannot make sense of the term 'sustainable development', unless I think of it as being an economy that develops in a way which is sustainable by the larger system, which supports the economy. If you see the economy as a subsystem of a larger finite nongrowing system, then the term 'sustainable growth' is rather shocking. How can you think of the economy as continually growing if it is the subsystem of something which is finite, nongrowing, and materially closed.

The point I want to make is that if you start with certain preanalytic visions, these determine very much the analytical questions that you will answer and focus on if the economy is a subsystem of a larger system that is finite, non growing, and materially closed. It then seems to me that the first analytical question one has to ask is: how big can the economy be before it disrupts the capacity of the larger system to sustain it; how big should it be to in order to satisfy our human needs, as well as the needs of other living beings; what is the proper division of the total life support system between human beings and non human life?

The World Bank was not interested in dealing with these questions, which is why the little diagram was not the right way to look at it. If you push that diagram on the growth economists, their reaction would be somewhat like a vampire presented with a crucifix: that is not the right way to look at it, take it away.

I think it is very important to put forward preanalytic visions, compare them, and see which one is fundamentally most convincing. I confess that for a long time I was pretty much for growth economics but I just cannot see things that way any longer. No matter how hard I try, it's just impossible for me to see the economy as an isolated box by itself, with inputs coming from nowhere and outputs going nowhere. And if that's not the right way to look at it, I guess I come down to looking at it the wrong way.

These were the remarks, which I thought I would share with you and I hasten to say, in closing, that I do not make these remarks in an effort to speak against the World Bank. My colleagues there were the best people I have worked with. The six years I spent there were very good for me, despite the fact that I saw things quite differently from the World Bank. Thank you.

ENVIRONMENTAL SUSTAINABILITY: EAT BETTER AND KILL LESS[1]

R Goodland[2]

INTRODUCTION: ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability means life-style changes to maintain natural capital. Keeping natural capital constant means maintaining the two environmental services – source and sink – unimpaired.(1) Most environmental sustainability will be achieved to the extent the world achieves the transition to renewable energy, and a stable population.(2) Much has been written on these two fundamental transitions; this paper outlines one other fundamental need instead: the topic of human diet. This paper is addressed to all those who are, therefore, concerned with accelerating the transition to sustainability; its purpose is to sharpen one segment of the sustainability debate.

Of all the important changes needed in order to approach environmental sustainability, the topic of human diet has been chosen because of five environmental reasons.

- First, there is no agreement that diet matters; not even that it is a legitimate issue for agricultural policy or for economic development. In fact, current global trends are hastening in the wrong direction, away from the sustainable course. An increasing number of analysts report that we are moving towards the limits of global food production.
- Second, diet is a poverty and equity issue. Diet concerns mainly the poor and not the rich. The rich will always be able to buy the diet that they want.

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- Third, much agriculture is not sustainable, and there is little agreement on what sustainability criteria are applied to the agriculture sector (FAO 1995; 1996). Instead, most marine fisheries and tropical forestry are cited as the two most obvious examples of the lack of environmental sustainability.
- Fourth, the expansion of food supply, under any scenario, makes the environmental impact of agriculture one of the most urgent and under-addressed predicaments of our times. The environmental impact of the agricultural sector probably exceeds the impacts of all other sectors, even the manufacturing and industrial sectors in many countries. Agriculture has degraded more natural capital and caused more extinction of species than any other sector. Accelerated loss of topsoil from croplands reduces productivity worldwide. Agriculture uses more water than the other sectors of the economy in many nations. Many aspects of agriculture can be heavy polluters (e.g., feedlot runoff, abattoirs, effluents from oil palms, rubber, coffee processing, irrigation, and salination). The energy consumption of agriculture is substantial in industrial countries and even more so in developing countries, due to factors such as diesel use in tractors, pumpsets, etc., and the energy contents of fertilizers and biocides (Cleveland 1995a; 1995b).
- Fifth, within agriculture, the case to demote cattle on the developmental, environmental, health, and poverty alleviation agendas is strong, and is intensifying. Cattle have arguably caused, or are related to, the most environmental damage to the globe by any nonhuman species (e.g., overgrazing, soil erosion, desertification, and tropical deforestation for ranches).

These five reasons combine into a compelling argument to promote environmental sustainability in the agricultural sector. Its lack imperils our world. As a quarter million more people must be fed each day, sustainability must be approached as a matter of great urgency. In addition, the ethical and health reasons for promoting environmental sustainability by adjusting diet are appended.

THE GLOBAL FOOD CRISIS

There has been no growth in grain harvest during the first five years of the 1990s. Global grain reserves fell to an all-time low in 1995. At the end of 1995, grain carry-over reserves dropped to 231 million tons, enough to feed the world for only 48 days. Previously, when reserves fell below 60 days, the price started to rise. In 1995, wheat and maize prices hit 15- and 12-year highs, respectively. The price of corn in China doubled over 1992–1995; the price of barley doubled in Europe over 1993–1995. Grain prices reached all-time highs on the Chicago Stock Exchange in March 1996. Rice prices started to rise in 1987 and have maintained higher levels in the 1990s, with a sharp upward volatility in 1993 and 1995 as carry-over stocks fell to 20-year lows (Harris 1996). Japan forecasts a doubling of world grain prices by 2010. Low-income, food-deficit countries will need to raise an additional $3 billion in 1996 for their food imports. With 26 countries facing exceptional food shortages, there is potential for crisis (Diouf 1996). Global cereal production must increase by at least four per cent in 1996 if food needs are to be met without drawing down reserves even further. As corn becomes scarce and expensive, there could be massive selling of US and other grain-fed livestock. The European Union (EU) has started to tax grain exports to prevent a rise in prices at home. Brown, Flavin, Kane (1996) attribute these trends to a combination of three successive poor harvests and to increased carnivory.

Around 800 million (FAO 1995) to one billion people lack sufficient food to function minimally. About 200 million children under the age of five suffer from protein and energy deficiencies (Diouf 1996). If adequate nutrients such as vitamins, iron, and iodine are considered, the number of malnourished may exceed 2 billion. 50% of these people live in South Asia; 25% live in sub-Saharan Africa, and about 10% in China. China is rich enough to buy grain; it is Africa that may suffer from future grain shortages. The world's population looks like it would jump by 50% to 8.3 billion by 2025. World food consumption will have to double by 2025 just to keep up with population increases, without reducing current hunger levels. The necessary tripling of food consumption over the next 50 years will need every conceivable help it can get; time is short. That has massive environmental implications which must be carefully assessed in advance.

There are only three choices to increase food production; none is encouraging.

1. *Extensification, or expansion of cultivated area.* There is substantial farmland lying idle,(3) especially where it has been taken out of cultivation by economic policy (e.g., parts of the EU), or because it is uneconomic or fallowing. Possibly, 25% of current cropland should not be cropped as it is degrading fast.(4) The rate of land abandonment or degradation may exceed the rate of cultivation of new land (Pimentel 1994; Kendall, Pimental 1994). As most accessible and fertile soil has already been cultivated, practically all of what is not yet cultivated is less available or unsuitable for agriculture, as it will be lower in quality and more prone to degradation. There may be up to 500 million ha of potentially arable land; but its productivity will be well below today's average. Much biodiversity will be lost by such conversion to agriculture, if conventional management practices are used. It is not by accident that the remaining wildlands, especially

tropical forests, are not cultivated. There are compelling environmental reasons why they were left, until now, in their natural state. These reasons differ from place to place – biodiversity values, habitat, erosion proneness, oligotrophy, inaccessibility, aridity, etc.

The abandonment of highly eroded or otherwise damaged land, and the conversion of cropland to nonfarm uses are accelerating, thus further reducing the potential to increase cropped area. Some degraded lands can be fallowed, thus providing time for rehabilitation. But there is not much such land to be rehabilitated. Rehabilitation usually takes several decades, and when rehabilitated to cropland, such sites remain fragile. Thus, there is little scope for expansion of agricultural area as a whole, although there is much regional variation. For environmental sustainability, most, if not practically all, expansion of cultivated area would probably impose greater environmental costs than food benefits.

2. *Intensifying existing cultivated area.* Here the outlook is not quite as bleak as that for extensification. There is little optimism in agricultural research centres. The International Rice Research Institute's (IRRI) prototype rice variety, announced in 1994, may boost yields by 10% under field conditions in about five years time. Apart from this, no major breakthroughs seem to be in the offing. IRRI's own rice yields have plateaued or are falling even under the world's most careful scientific management. Japan's rice yields have ceased rising despite unlimited money and the best management available.

The prospects are not bright for a repeat of technological fixes that reaped major gains in the Green Revolution's high-response hybrids. Much of the Green Revolution's productivity increases came from increasing energy intensiveness – by 100-fold in some cases (Kendall, Pimentel 1994). Fossil energy has now become too expensive for that to be repeated. Part of the Green Revolution's success stemmed from using, vastly, more water. As water has now become the limiting factor in agriculture, that is less of an option for the future. Introducing nitrogen-fixation(5) into grains seems little closer than it did two decades ago, despite much research. The rate at which new crop varieties are introduced is declining. The rise in grain yields per hectare during the late 1980s and early 1990s has slowed dramatically. From 1990 through 1993, worldwide grain yield per hectare declined.

There is much scope for raising developing country yields in the direction of OECD yields. Certainly, vastly more agricultural research is essential, but it will be increasingly difficult to match population growth indefinitely. Agriculture's share in total official development finance has declined from 24 to 16% ($10 billion to $7.2 billion) between 1982 and 1992 (Diouf 1996). Demand-side management, population control, loss reduction, and eating more simply also will be essential.

Overgrazing is increasing on every continent. Rangeland beef and mutton production seems unlikely to increase much, leading to a steady decline in per capita supply. The cumulative effects of soil erosion have reduced the potential of perhaps one-third of the world's remaining cropland.

Most major ocean and freshwater fisheries are in decline. Unsustainable catch sizes have exceeded regeneration rates for so long that the fish resource itself is damaged. Pollution and destruction of estuaries, mangroves, wetlands, and other fish habitat intensify these trends. Seafood per person probably peaked in 1989. Formerly eaten mainly by the poor, prices are now so high that only the rich can afford to eat much seafood, and this situation seems likely to worsen in the future. Fish and other aquatic protein provide less than one per cent of the world's food today. Measured as protein, it is less than five per cent. While this makes a big difference to many of the world's poor, it is less significant for global food supplies. From now on, fish consumption seems likely to decline from 19 kg/person to about half that in the next couple of decades. Fish used to be cheap because they concentrated their dilute but very widely spread food source, plankton, which, in turn, feeds on sunlight and water.

Aquaculture,(6) the farming of aquatic resources low down the foodchain (fish, mollusks, crustaceans, and aquatic plants such as seaweeds), could substitute for some natural seafood and river fish. Productive aquaculture depends on manufactured inputs (grain, starches, fishmeal, diesel), hence lower efficiencies, rather than on autotrophs (green plants) as do 'natural' aquatic resources and traditional (low input) aquaculture. But even so, aquaculture is probably more productive and has much less environmental impact than its competitors' livestock.

Similarly with irrigation: there is restricted scope for expansion of irrigated area, although there is much scope for improving current irrigation efficiencies, retarding salination, and improving land tenure. Water is the main limiting factor for world agricultural production (Kendall, Pimentel 1994). 40% of the water is abstracted for irrigation. A large amount, therefore, never reaches the fields. But the fact is that irrigated area per capita has begun to decline; irrigation is falling behind in the quest for increased food production. The trend in irrigated area per capita has been negative since 1978 (Postel 1992). Aquifer abstractions in major food-production areas exceed replenishment rates, which has led to a fall in levels. Aquifers are receding as much as 1-5 m annually in the major croplands of China and India. Irrigation water, thus, becomes more expensive and is diverted from agriculture to cities: the world's cities are growing at the rate of one million people each week.

There is decreasing scope for additional fertilizers; world fertilizer production and per capita use peaked around 1989 and seems to be mainly in the decline since then. Diminishing returns may have begun to bite. R & D on intensification demands high priority, as substantial cultivation still does not use fertilizers. Most fertilizers (60%) are used on grain; adding oilseeds and cattle fodder increases this to 75%. The remaining fourth is applied to legumes, vegetables, fruits, tubers, sugarcane, cotton, and other fibers (Brown, Flavin, Kane 1996). As irrigation efficiencies improve, the margin for error shrinks. Climate instability increasingly risks yields; losers are likely to vastly outweigh winners.

Both these options simplified above will need to be strenuously accelerated. Major yield increases and loss reductions are essential in the forthcoming decades even if population increases keep slowing down. The purpose of this outline is to suggest that as it will be increasingly difficult to feed the world, the third option will become more important than it has been until recently.

3. *Feed grain and vegetables to people rather than to livestock.* This could increase consumption without any increase in production. Many more people could be well fed on grain-based diets, become healthier, and at much lower environmental and social costs than on meat-based diets.(7) Most meat now comes from grain-fed animals. When farm animals were fed largely on surpluses and farm wastes, they acted as valuable buffers evening out fluctuations in food supply, being used for traction and providing manure. That idyllic era is over. Animals are increasingly the main consumers of grain formerly eaten directly by humans.

Most nations were basically self-sufficient in food until the early 1960s; now only a few are (Kendall, Pimentel 1994). Until recently, Former Soviet Union (FSU), Taiwan, and China were substantial exporters of grain; now all import heavily. FSU and China are the first and second largest grain importers. Mexico became a net corn importer in 1996, two years after the implementation of North American Free Trade Agreement (NAFTA). Mexico seeks to borrow finance to pay for importing 6 million tons of corn to meet demand at a time when there is little to be had on the world market. Mexican consumption per person of maize, beans, and wheat dropped an average of 35% over the past decade; this has led to increasing social unrest, starvation, and grain train robberies. Bangladesh became a big rice importer in 1995 after years of self-sufficiency. Now, only Canada and the US are major grain exporters. The Food and Agricultural Organization (FAO) predicts global rice stocks will fall for the fourth successive year (Yap 1996).

Only 17% of China's grain went to livestock in 1985; by 1994, this figure had risen to 23%. This compares with the 68% of the grain fed to livestock in the US. As animals' conversion efficiencies of grain to meat are so low, trends towards carnivory exacerbate food supplies. This is rarely raised in sustainability debates, and, even more rarely or not at all, in development policy setting.

The prospects for increasing the supply of food by expansion of cultivated area are not promising. The prospects for intensification are somewhat more promising, and merit great attention. But we must also look at the demand side. Of course, there is much recognized scope for reducing losses. But one less recognized area for major gains is eating lower down the foodchain. Vast amounts of food are wasted by inefficiently converting grains into meat. Eating lower down the foodchain would improve health and food supply.

EATING MORE SUSTAINABLY

Affluent people in OECD countries consume about 800 kg of grain indirectly (Brown, Flavin, Kane 1994; Durning, Brough 1991), much of it inefficiently converted into animal flesh, with the balance as milk, cheese, eggs, ice cream, and yogurt (Table 1). Such diets are high in fats and protein, and low in starch. In contrast, in low-consuming countries, annual consumption of grains averages 200 kg per person, practically all of it directly, with high inefficiencies in conversion. Such diets are rich in starch and low in fats and protein. The grain consumption ratio between rich and poor countries is about four to one (Brown, Flavin, Kane 1994).

Feedlot cattle consume 7 kg of grain to produce a single kg of liveweight. Pork takes nearly 4 kg of grain per kg of liveweight. Poultry and fish are more efficient converters, needing about 2 kg of grain for each kg of liveweight produced. Cheese and egg production are in between, consuming 3 and 2.6 kg of grain per kg of product, respectively (Brown, Kane 1994). Where animals are restricted to recycling products (household scraps, peelings, agricultural residues) that would otherwise be wasted or would pollute, they must be ranked as efficient converters.

Table 1. *Grain use and livestock consumption [1990; per capita; kg rounded to the nearest 100 kg (Brown 1995)]*

Country	*Grain use (kg)*	*Consumption*						
		Beef	*Pork*	*Poultry*	*Mutton*	*Milk*	*Cheese*	*Eggs*
US	800	42	28.0	44.0	1.0	271	12	16
Italy	400	16	20.0	19.0	1.0	182	12	12
China	300	1	21.0	3.0	1.0	4	—	7
India	200	—	0.4	0.4	0.2	31	—	13

Source. Brown, Kane (1994).

FAO (1995) calculates that almost 50% of global grains are fed to livestock. The two countries converting the most grain into meat are the US and China – 160 and c.100 million tons, respectively (Brown 1995). Developing countries' élites are eating increasingly higher up in the foodchain. Developing countries' animal consumption between 1960 and 1990 soared to 48% for large ruminants, 53% for small ruminants, 200% for hogs, and 280% for poultry. Little of this reaches the poor. Increased grain importation into developing countries is to feed 'animals that are consumed by the minority higher-income sectors of society' (FAO 1995). The question, therefore, becomes: would the world's more affluent be willing to simplify their diets for whatever reason – health, ethics, equity, environment, economics, or religion? Would the grain thus freed be distributed to prevent famine and hunger, where and when needed?

Not only are mammals inefficient converters, their production is environmentally costly in terms of water used and greenhouse gas generated. The production of one pound of beef consumes over 2700 gallons of water, whereas grain production consumes less than 200 gallons, and vegetables about half that. FAO (1995) points out that methane from cattle contributes 2.5% of global greenhouse gas (GHG) production. Cattle contribute about 60 million tons of GHG per year, slightly less than rice paddies (70), but more than burning vegetation (55), gas drilling (45), termites (40), and landfills (40).

Food prospects relate closely to poverty and equity. The poor commonly allocate 70% or more of their incomes to food; the rich allocate less than 10%. A few good harvests could conceivably restore food stocks, but climatic instability seems to be increasing. This highlights the need for a rapid transition to renewable energy to reduce GHG. Climatic instability will vastly reduce the likelihood of successive bumper harvests in the future. The 1995/1996 winter ozone hole over the Northern Hemisphere was undoubtedly the largest on record. This is likely to increase risks to the world's largest wheat areas as well as to the plankton–fish foodchain. Climate instability in 1996 is constraining yields in China, US, Canada, and parts of Europe. Agricultural development and food policy workers need to support their colleagues to promote climate stability, and the transition to renewable energy. Sustainability in food supply will be impossible unless the demand side is also stabilized. This means stable human numbers eating more efficiently on the foodchain (Figure 1).

One acre of cereals can produce 2 to 10 times as much protein as an acre devoted to beef production. One acre of legumes can produce 10 to 20 times more protein than an acre in beef production. The UN World Food Council calculates that 10 to 15% of cereals now fed to livestock is enough to raise the world food supply to adequate levels (Goodland, Ledec, Watson 1984). In summary, raising livestock is more destructive in depleting topsoil, groundwater, and energy resources than all other human activities combined, as well as

↑ **Worst**
Most impact/most sentient/least efficient/least healthy

1. Mammals: swine/cattle/goats/sheep/rodents/lagomorphs/camelids/deer/eggs/cheese/milk/butter/leather/fur (wool)

2. Birds: chickens/geese/ducks/pigeons/turkeys

Homoiotherms (warm-blooded)

Poikilotherms (cold-blooded)

3. Fish/lizards/saurians/amphibians

Vertebrates

Invertebrates

4. Crustaceans/insects/(silk/honey/propolis)/annelids/mollusks

Heterotrophs

Carnivory

Vegan

5. Saprophytes: fungi/yeast/other microbes

6. Autotrophs: legumes/grains/vegetables/starch crops/fruits/nuts/algae

↓ **Best**
Least impact/least sentient/most efficient/healthiest

Figure 1. *Environmental and bioethical foodchain ranking*[8]

causing enormous environmental damage, such as clearing of forests, destruction of wildlife habitat, and pollution of rivers and lakes (Regenstein 1991).

GRAIN-BASED DIET

Grain-based diet is a matter of degree. Human societies differ in what diet they find comfortable. There is a continuum from eschewing red meat, then 'white' meat (poultry), then mammals, or all terrestrial animals (Figure 1). Some people draw the line between eating warm-blooded animals and cold-blooded animals. This means some people eat fish but not rabbits or chickens. The next stage on the continuum is to eat only invertebrates, shrimp, or shellfish, for example. Ovo-lacto-vegetarians eat animal products (eggs, milk, cheese), but not the animal itself. Vegans eat no animal products of any kind. Ethicists try to interpret peoples' behavior, but people often are neither strictly logical nor consistent in their diets. Nor need they be. Flexibility and opportunism in diet are valuable, especially for the poor.

The encouraging congruence of environmental impact with food conversion efficiency, health, and degree of sentience argues for promoting herbivory and demoting carnivory for those wanting to lessen both environmental and ethical damage. Mammals are more sentient and seem to suffer more than invertebrates or plants. As degree of sentience influences diets in the same direction as environmental impact, a shift away from carnivory will improve both. Animals suffer, that's why we flog horses and not trees. Horses are higher on the sentience scale than trees. But the sentience scale is not totally consistent with the environmental or ecosystemic scale. The environmental impact of felling one tree greatly exceeds the impact on the ecosystem of swatting a gnat.(9)

The 'higher' the animal is in evolutionary terms, the more people are reluctant to eat it. Few educated people would knowingly eat a primate, for example; many more will eat an oyster. Sentience and pain guide some dieters. If an animal is thought not to feel much pain (e.g., shellfish) or not to be very sentient (e.g., prawns), such people are more likely to eat them. 'Factory' farmed animals (e.g., veal from calves immobilized in a cage from birth to death; debeaked and declawed battery chickens) are avoided by some people who will eat less-intensively farmed animals. Some wear leather shoes, but would not dream of eating beef. Eating eggs, butter, milk, and cheese, produced, of course, by females, implies that c.50% males born will be eaten sooner unless they are used for draught. The females are also eaten as soon as they finish producing. Some even question silk use as it means that millions of cocoons were boiled alive.

Where one is comfortable on this continuum is not the issue here. The issue is that when people get richer, they tend to move up the foodchain and eat more meat. This partly explains why the world is hurtling away from sustainability. Other reasons include rapid population increase and dependence on coal. For sustainability, and to avoid hunger or worse in poorer societies, we have to descend in the foodchain; eat less meat; and move towards a grain-based diet. The most needed transition is towards eating mainly autotrophs and saprophytes, and less heterotroph products, especially homoiotherms. This would buy valuable time to implement other prudential measures on the transition to a sustainable society and would postpone the onset of worse environmental damage. Our inchoate, but nonetheless felt, ethical perceptions indicate that feeding higher on the foodchain is morally (intrinsically), as well as ecologically/economically (instrumentally) worse than eating lower down the foodchain. We have to reverse the direction.

Eating lower on the foodchain reduces the environmental damage and suffering caused by overconsumption and excessive population. This is a lifestyle change that most individuals can adopt if they want to consume less of the earth's carrying capacity or reduce their 'ecological footprint'. Both our health and that of the planet would improve. Hunger, starvation, and malnutrition could be alleviated by such trends. Voluntary population control and better diets are preferable to starvation, disease, and deteriorating environments.

If humanity moves down the foodchain, the saved carrying capacity should be used to alleviate the hunger of the poor as the first priority, although further redistribution will also be necessary. Should the second priority be to support more wildlife or more low-consuming humans? At the present margin, we should opt for more wildlife. After human population has been much reduced by natural causes, the world could reach a balance beyond which more humans would be better than more wildlife. This intuitive conjecture would be a luxury for the future.

This paper specifically does not advocate that everyone should adopt grain-based diets immediately.(10) The changes needed are gradual and relatively modest; nothing draconian. Most importantly, rich people now eating high on the foodchain would improve their health by continuing to move down it somewhat. Encouragingly, this powerful trend has started. For example, annual US beef consumption peaked in 1976 at 95 pounds per person; in the 1990s it has stagnated around 66 pounds. US beef consumption grew at only one per cent between 1990 and 1995. European, especially UK, beef consumption never reached those levels, but is falling faster than in the US. EU consumption of beef and veal fell six per cent between 1990 and 1995.

The countervailing trend is for people to eat more meat as they become richer. China's pork consumption, for example, jumped 14% in 1995 alone (Brown, Flavin, Kane 1996). Current incentives to move higher on the foodchain need to be removed in order to promote sustainability and to reduce hunger. If people of increasing wealth, now low on the foodchain, could be encouraged to stay where they are, rather than climbing up, that would help greatly. The poor, already low on the foodchain, should be encouraged to stay there by improving their food security, and enriching the variety of diet such as by increasing fruits, vegetables, and nuts. Both educational campaigns and incentives (e.g., school feeding, maternal and child nutrition education, coarse grain and other ration shops) will be needed to foster such life-style changes. Removal of subsidies for livestock, both direct and indirect, should be the first step.

In summary, of the three diet-classes of people, first, most people of the world (those already at the efficient, low impact end of the foodchain) would remain as they are. Second, affluent people now consuming more meat would consume more efficiently lower down the foodchain. Third, people starting to move up the foodchain (e.g., China, India, etc.) would be encouraged to stay where they are.

Taxes have to be shifted away from things we want more of (employment, payrolls, value-added), and onto things we want to discourage (throughput, inefficiency, waste, pollution, overuse of renewable resources such as overharvesting fish, and severance taxes on minerals and coal) (Daly, Cobb 1994; von Weizsäcker, Jesinghaus 1994).

Incentives are needed to promote grain-based diets by applying good economics and good environmental management to food and agriculture. In particular, conversion efficiency and 'polluter pays' principles should be used in setting the 'full price' which internalizes environmental and social costs. Cattle feedlots and slaughter houses consume much water and generate highly polluting waste. These need to be internalized. Just as society taxes fuel inefficiency in cars, it should also tax conversion efficiency in food. Highest taxes(11) would fall on the least efficient converters, namely hogs and cattle. Slightly lower taxes would be assessed on sheep as they graze natural grassland more than do cattle. Taxes would be lower on free-range poultry recycling household wastes than on cattle; even lower on rodents and lagomorphs which eat wastes or are not fed.

If such sustainability and poverty-alleviating measures become widely adopted, mammalian flesh consumption would decline and would consist mainly of males not needed for draught and females when they have finished producing milk. Hogs and poultry would be kept mainly to recycle wastes; their meat would be an occasional by-product. Ruminants would be restricted to natural range unusable for more intensive production. Aquaculture fish would become more widespread than today.

Higher taxes would be levied on animals overharvested from the wild such as whales and most major fishery species. Human society so far seems incapable or unwilling to harvest sustainably any product from the wild. All harvests from the wild are in decline: great whales, cod, tuna, herring, mackerel, tropical timber, most natural tropical or temperate forests, even natural rangelands harvested by cattle. Taxes (fines) are already legislated for killing rare or endangered species in many countries. As their enforcement is weak or absent, that needs to be reinforced.

No taxes would be paid on grains (rice, maize, wheat, buckwheat, etc.), starches (potatoes, cassava), and legumes (soy, pulses, beans, peas, peanuts, etc.). Modest subsidies on coarse grains (millet, pearl millet, sorghum, etc.) would alleviate hunger and are unlikely to be abused as the rich will not eat them. West African élites have abandoned indigenous grains (millet, sorghum), and have substantially converted to imported wheat and rice. Fortification of cereal four with Vitamin B complex, iron, and calcium, and adding iron to salt are highly cost-effective, especially where diets are too high in roots and tubers. Encouragement for domestic or village-scale beneficiation, such as of peanuts to peanut butter and cashew fruits to roasted nuts, often doubles or triples the profit to the grower. The use of green manures should be promoted before an automatic recourse to chemical fertilizers, and that of cheap crushed limestone before fancier types. As much as 40% of food produced is lost to pests, spoilage, damage in transport or cooking, etc., before being consumed. Therefore, crop loss reduction in field, storage and transport by accelerating IPM has much scope. Adoption of such policies will not solve world hunger overnight, but it will certainly help.

This major opportunity to improve development is rapidly becoming more widely discussed (e.g., Kendall, Pimentel 1994; Brown, Flavin, Kane 1994; Brown 1995; Cohen 1995; Ehrlich, Ehrlich, Daily 1995; Goodland, Ledec, Watson 1984). Even so, some people still find these proposals too sensitive and controversial. On the contrary, ignoring this opportunity to improve nutrition, and reduce poverty, environmental impact, and hunger by dietary improvements would be more controversial, uneconomic, and arguably immoral. We have let the world become so full that there is unfortunately already a trade-off between human numbers and diet. Kendall, Pimentel (1994) estimate that a world population of 7 billion could be supported at current levels of nutrition on a vegetarian diet, assuming ideal distribution and no grain for livestock, but without alleviating current hunger levels. Cohen (1995) writes that c.2500 kcal of food are needed for a vegetarian diet, but this figure soars to 9250 kcal if our diet is 30% from animals. This high figure (9250 kcal) means 3.7 times as many edible calories would have to be grown or grazed as are eaten.(12) If people eat some meat, only about 2.5 billion could be provided for; this excludes nearly two out of three people alive today. This is why it is so important for the world to remain low down the foodchain, for those high, to descend, and to discourage people moving up.

NONFOOD AGRICULTURE

Land allocated to production of products other than food will increasingly be scrutinized and decreased to the extent possible. The trade-offs between cotton and synthetic fibers need to be environmentally assessed. Land allocated to tobacco production should be taxed higher than for grain-fed beef production. Land allocated to potable alcohol production would also be taxed.

Alcoholic beverages divert much grain; they should also be taxed on conversion efficiency: slightly lower on beer and higher on grain alcohol (gin, whisky) and starch alcohol (vodka). Grapes grown on rocky hillsides and not displacing food crops would be exempt. So some wine, brandy, and chacha (grape vodka) might escape. Molasses, a by-product of cane-sugar production, is often released into rivers where it is highly polluting. Potable spirits distilled from molasses (cachaça, rum, etc.), which otherwise would be unused, might also be exempt. Tequila and pulque from Agave hedges might also escape. Because some fermented starch products (e.g., cassiri, gari, etc.) contain more nutrients, vitamins, and amino acids than the original starch, they can be more nutritive than the unfermented stage. *Lactococcus lactis* produces lactic acid and antibacterials when fermenting rice cakes. These products conserve the rice and prevent diarrhea in recently weaned infants. In addition, many fermented products last longer than when unfermented, and can, therefore, act as buffer or carryover stocks in times of glut.

This conversion-efficiency sliding-scale tax should be refined by adding the 'polluter pays' principle. Polluting cattle feedlots and meatpackers would be taxed highest; domestically-fed rodents and lagomorphs the least. If biodiversity and habitat destruction is included in environmental damage, then cattle raised from pastures created from rainforests would be taxed highest. Natural range cattle (e.g., Maasai pastoralists in Kenya; US buffaloes) would incur a lower tax. Unilever and the World Wide Fund for Nature (WWF) award stamps of approval for sustainable fish products. The Forest Stewardship Council and WWF award logos to sustainable timber products. These empower consumers to promote sustainability by their purchasing behavior. Such consumer sovereignty is now needed to encourage food conversion efficiency, improve health, and reduce environmental impact.

Governmental and public R & D investments should be restricted to zero tax foods. Least-efficient converters and livestock should not be supported by public funds. There may be a minor role for peri-urban dairy, but that is best supported by the consumers and the private sector. Livestock on natural rangeland unusable for cultivation should be supported by landowners. Practically all such R & D should be focused on grains, especially coarse grains, starches, legumes, and vegetable oils. There are useful returns to R & D on fruits, nuts, seasonings, micronutrients, and vitamins.

As the environmental impact of obtaining cooking fuel can approach the impact of food harvesting, substantial attention should be given to the environmental sustainability of cooking methods and its fuels. Such measures as the use of solar cookers, fuelwood hedges, efficient stoves, and pressure cookers would decrease the environmental impact of gathering fuelwood and burning agricultural residues. Recycling wastes merits higher attention too. Mulch, manure, agricultural residues, nightsoil, and carcasses(13) are concentrated forms of nutrients. Their recycling decreases the need for fertilizer.

SELF-DEFENSE OR RETRIBUTIVE KILLING

Humans share this world with many nonhuman species. Most societies today impose limits on killing wildlife. Legislation in some countries provides for shooting game poachers on sight and shooting tree poachers in others. But sharing space with nonhuman species raises competing moral claims. The society wants to conserve some wildlife, yet meeting the demands of one claimant (e.g., pastoralists, trophy hunters, etc.) precludes meeting the claims of others (e.g., ethicists, wildlife conservationists, elephants, migratory animals, etc.). This is the moral dilemma(14) we seek to resolve.

Wildlife is currently killed for many reasons; some legal, some illegal. One obvious end of this spectrum of reasons for killing is self-defense. Clearly, most people would shoot the wolf attacking themselves, their family, or another person. A village is likely to kill the crocodile that has just eaten someone. Most people would not hesitate in killing people-eaters either in self-defense or in retribution. Such animal control is clear restitutive justice, and has general consensus. Similarly, rogue elephants killing a human would also be shot. Animals that eat people offer the extreme justification, and is extended to animals seriously wounding humans.(15) Self-defensive and retributive killing blurs with the next grade on the continuum, namely culling.

CULLING

Culling normally involves the deliberate scientific reduction of animal numbers that have exceeded the carrying capacity of their habitat now restricted by human appropriation. Because humans have appropriated so much wildlife habitat and removed so many predators, culling is resorted to in order to benefit the species, and partly other species that may be threatened by its own overabundance. Predators are removed precisely in order to augment the number of prey animals for hunters (e.g., wolves are killed in Alaska to augment caribou and elk for hunters). Prevention of overgrazing or deterioration of the habitat ensures that the culled population survives; starvation of the majority is avoided by culling the few. Culling one species prevents greater harm to another species and to the ecosystem as a whole. Human carnivores argue that the products of culling should not be wasted, such as meat, hide, and horns.(16) Restaurants are well supplied with meat from culled wildlife. Biocentrists and animal rights ethicists have major reservations about culling.

Culling has become ecologically essential because society has co-opted most wildlife habitat and has broken natural predator/prey controls. However, it remains unacceptable to biocentric ethicists. Just like use of fire and grazing, culling has become a management tool. Human encroachment into wildlife habitat means that natural population controls have been disrupted so that wildlife pressures may exceed carrying capacity of the remaining habitat. The lesser harm of culling thus prevents the greater harm of starvation of that species. Much of this argument devolves on the conspicuousness of US deer. Luke (1995) points out that 98% of US animals hunted are not deer, but no one complains about their overpopulation. Increase in culling will decrease damage to humans, property and crops. Culling converts wildlife into a renewable resource – to the extent sustained yield is achieved, which is dubious. Assuming the less fit are culled first, which is far from the case, there is selective benefit in culling, just as predators (wolves) are said to improve their prey populations (deer).

For human pets, we prefer birth control to culling, although the latter is widespread. Now municipal pounds kill animals not adopted within a time limit, and mandate sterilization for all animals on adoption. Abandoned-pet pounds find that this decreases (somewhat) the need for official culling. Sterilization is now widespread in pest control worldwide.

After altruistically culling for the good of the species, the next level of culling is to reduce competition with humans, or, rather, their livestock. 'Pure' culling conserves the species and has no primary aim to benefit humans. Culling grades into hunting.(17) In such cases, the distinction between sport hunting and culling is blurred. Sport hunting at the extreme is clear. The sports hunter pays the landowner for the privilege of being permitted to shoot animals belonging to the landowner when there is no need for culling.

Society still condones culling for some species in general (e.g., deer in the US and zebra in South Africa), but prefers sterilization or contraception for individuals.(18) Selling culling rights is tantamount to trophy hunting. Human society is divided on elephants. They seem to be on a transition from 'no objection to culling' towards preference for measures other than culling. While elephant culling may, in some theoretical sense, be ecologically suggested, it is unlikely to be acceptable to the general public, much less to the world's increasing numbers of animal welfarists, humane societies, ethicists, and animal rights groups. Some countries and provinces permit sport hunting. Most people accept retributive killing, many will accept culling if it is explained in advance. Fewer people nowadays are keen on trophy hunting.

To what extent can culling become cropping (i.e., sustained yield)? Can this be made lucrative, while achieving the aims of culling, and preventing human greed from overhunting, poaching, and damaging the potentially renewable resource as has happened widely? Clients are willing to pay US $40 000 to shoot an elephant, and $50 000 to shoot a rhino in this way, so there may be scope to make some culling profitable. If a rogue elephant has to be found and shot, a sports hunter may be called in, who would pay well for the privilege. The hunter would have to be previously qualified and listed as someone who wants to buy that privilege when it becomes available. Culling nonrogue elephants is more problematic as a whole family group may have to be shot. This may include gravid females, newborns, and calves, rather than adult males, the conventional goal of sport hunters. Well-organized and controlled deer hunting in the US is an example of the hunters succeeding in regulating the cull and caring for deer habitat. Scientists would have to rule when culling is necessary, for how many animals of what species, etc.

TROPHY HUNTING

Trophy hunting can, in no way, be subsumed under the previous two categories of killing animals: self-defense and culling. Trophy hunting is for the sole purpose of collecting a dead animal trophy, and, hence, serves no purpose for wildlife or humans, today or in the future. It serves the interests of a tiny segment of society at the expense of mankind. If the fees from rich trophy hunters is allocated to wildlife conservation or poverty reduction, there may be a minor economic benefit. This is probably vastly outweighed because 'legal' trophy trade exacerbates illegal trophy trade.

Some hunters are not content shooting zebras or deer, or killing less fit animals first. Many hunters, therefore, kill fit adult males. In few exceptionally well-managed countries (The Netherlands), the hunt controller ensures that the less fit are shot first. Adult males are not shot at all until the less fit have been removed first. From the evolutionary biological point of view, much trophy hunting weakens the species fitness as it takes prime animals. Predators, on the other hand, eat the weak, old, and infirm, thus improving the remainder. Zebra and deer trophies are not highly prized. Such hunters often give away the meat, and there is no great interest or trade in zebra hides. Much trophy hunting is not for the hunt itself but for competing with fellow humans. Wall trophies are compared with fellow hunters, especially the rigors involved. Technology controls (e.g., against machine guns and helicopters) are more to prevent 'cheating' by fellow hunters, rather than for the intrinsic respect for the prey. Green hunting – paying to shoot photographic films, contraceptives, or tranquilizers into a specific animal, for example – should be exploited to the full.

Translocation of humans is normally not very successful, whether spontaneous and voluntary or not, such as transmigration from Java to Indonesia's Outer Islands, and in the Brazil's Amazon forest colonization schemes. Similarly, faunal rescue from reservoir filling has been largely discredited. The theory against such 'Noah's Ark' publicity opportunities is that many ecosystems into which salvaged animals are released are already at carrying capacity, and, therefore, the released animals die. Only when admittedly costly translocation and other methods (e.g., contraception) cannot solve ecosystem degradation and other problems, should culling be contemplated.

KILLING FOR FOOD

Biocentric ethicists find the case for killing animals for food lame, environmentally damaging, and likely to brutalize carnivores. The life of an animal is a good; taking that life is bad, they claim. The bad may be outweighed if it permits a proportional benefit to anthropocentric humans, such as postponing hunger or malnutrition. The intrinsic value of life means we should not kill unnecessarily (see 'retributive justice' above). This section excludes subsistence hunting, which is outlined below. If slaughtering poultry and livestock is acceptable, then, it is argued, so must killing wildlife for food. Sport hunting, even for food, is unethical and unacceptable to increasing numbers of people for three reasons.

First, the justification of hunting for sentimental or masochistic gratification is weak. Seeking pleasure from inflicting pain or worse in others is immoral. Second, game is defenseless against high-powered firearms with telescopic or, increasingly, laser-sights. Historical accounts prate about 'fair game', pseudochivalry, where the animal may theoretically escape. Certainly, many hunters spurn docile or fenced prey; were hunters' dominance absolute, there would be no fair chase. Hunters' invocation of the thrill of the chase, outwitting the prey, and the risk involved ring hollow. Competition against human intellect is unbalanced. Most hunters would not use launchers or machine guns, but balances achieved maximize hunters' pleasure, not improving the chances of prey to escape. Third, if the game is a rare species, then impoverishing biodiversity bolsters the case against hunting.

The reasons biocentric ethicists find hunting ignoble are noted above. Hunters claim they conserve the habitat of their quarry. That may be true, such as in the case of the white-tailed deer in northeastern US, but the reason is selfish. Hunters conserve habitat by bag limits, hunting seasons, and enforcement at the public expense so that breeding populations are maintained. This provides hunters with enough animals to kill. If hunters are concerned with habitat conservation or species survival, there are many more effective ways to achieve it than hunting. If people want to 'rough it' for a day or a month in wilderness, they should be encouraged. It may do them good and make them better citizens on return. Society should provide more wilderness opportunities for humans and more wilderness for its denizens. But, spending time in wilderness should not be at the expense of game or its habitat. In certain wilderness areas, degradation is reduced by having to carry in one's fuel, food, and water, and to carry out the remains. The current need is to reduce damage to ecosystems by restricting cattle and human pressures on them. This provides time for ecosystems to regenerate themselves.

The method of killing influences some people strongly. Humane killing is better than painful killing. Faster death is better than lingering death, hence bow hunting is worse than rifle hunting.(19) Ethical hunters hope to kill instantly. Some societies rule that the prey be standing still before it can be shot. But many hunters do not practice to improve their marksmanship, which suggests less care is attached to killing instantly. Hunters acknowledge that a clean kill is better than crippling their prey, and say that inflicting needless pain is wrong. But if that is their goal, it can readily be achieved by not hunting.

The remaining argument is against killing animals expressly raised for meat or pelt. The case against slaughtering bred animals is not quite as strong as that against killing wildlife. Some people wear skins from ranch-bred animals, but balk at wearing skins from animals trapped from the wild. Some people wear 'ranched' mink, but not trapped ermine. People invoke the utilitarian argument; animals are here for us to raise and kill for food, thus denying the intrinsic value of other species.

Cobb (1991) finds domestication of animals solely for carnivory to be a greater problem than hunting from the wild; there is more suffering from the ways in which domestic animals are raised than in the way they are killed. Eating range-fed beef is less bad than eating factory-farmed beef on this score. Certainly, there is much unnecessary suffering during the life of domestic animals. Veal calves incarcerated for life in crates, and debeaked battery chickens have been mentioned. But objections to factory-farmed animals are broader and seem to devolve on the quality of life in addition to the method of killing and utilitarian use.

Cobb (1991) commendably advocates expanded wilderness, but would permit carnivory to be satisfied by hunting. Hunting in the wilderness cannot be controlled in many countries today and even less so in the future as land hunger intensifies and governance weakens. So, hunting is tantamount to extinction. Hunting is not *a priori* more humane than the most humane slaughter of domestic animals. The more urgent steps seem to be to vastly improve the humaneness of slaughter, and make it increasingly rare by restricting meat production to a by-product of animals recycling kitchen wastes and providing manure.

SUSTAINABILITY IN WILD FOOD

Sustained yield has proven elusive worldwide. The Canadian Government failed to achieve sustained yield in the single species cod fishery in spite of many decades of work by armies of fish biologists and statisticians. FAO calculates that sustained yield is not being achieved in fisheries. Almost every major ocean fishery is in decline, and many of them seriously so. For different reasons, IRRI is failing to sustain rice yields even under almost hydroponic conditions.

According to FAO, sustained yield has not yet been achieved in tropical forestry, and is less likely as time goes on, as population pressures intensify, and governance weakens worldwide. Sustained yield from natural tropical forests may have been achieved in Burma up to the 1960s, but that was with the relatively oligospecies seasonal teak forests using elephants. Some examples of sustained-yield forestry were included in FAO's draft (e.g., Hawaii, Queensland, etc.) but they were subsequently disputed. This argues for the prompt transition from natural tropical forest mining to tree plantations on nonforest land. The point is that as sustainability has not been achieved in harvesting from natural forests, it is likely to be more difficult to achieve by hunting animals from the wild. Global experience with utilization of the dozen species of great whales is similarly gloomy.

Some societies harvest food animals sustainably from the wild, such as the Aleuts, Inuit, and Sami (Lapps). This has a low impact as long as the animals used are for subsistence consumption by the societies themselves. The moment such subsistence hunting (a means of survival) becomes market hunting (to sell meat to a market), risks of unsustainability escalate. Selling polar bear skins or meat, for example, would create major risks to the species. It is difficult to list examples where biological sustained yield has been achieved by modern societies in a natural potentially renewable resource. Marine algae collection is not yet reported as exceeding regenerative capacity. Collection of medicinal plants can be sustainable and valuable for the poor. Sustained yield use – nonextractive ecotourism – of large wildlife or charismatic megafauna may be attainable in certain places outside zoos.

THE HEALTH ARGUMENT

The fact is that if energy needs are obtained from grain-based diets, then protein requirements will be met. Cereals supply 50% of dietary protein and calories overall, and up to 70% in developing nations (Harris 1996). As most poor people worldwide are forced to eat grain-based diets and little else and still survive, there should be no argument that eating lower on the foodchain risks health. Now even orthodox western health authorities cannot muster arguments strong enough to satisfy meat lobbies. Italians eat less than half the amount of beef and poultry that Americans eat (Table 1), yet they have a higher life expectancy. Part of this may be related to diet.

Problems arise when energy requirements are not met by grain-based diets, but from low-protein staples such as roots, tubers, bananas, and sweet potato. That highlights the importance of legumes and proteinaceous seeds (sunflower, sesame, etc.), particularly for vulnerable groups, such as infants. Many studies of extreme or vulnerable groups (pregnant women, infants, macrobiotics, athletes, oldsters, wounded, Trappists) reconfirm the adequacy of eating low on the foodchain (Barr, Janell, Prior 1994; Beardsworth, Keil 1993; Dwyer, Loewe 1994; Harland *et al.* 1988, Herens *et al.* 1992; Janelle, Barr 1995; Jensen, Slorach, Astrup-Jensen 1991; Mangels, Havala 1994; Sharma, Sharma 1991; Varner 1994; Weinstein, Austic, Schwartz 1992).

The other side of the argument is increasingly clear. Western carnivory kills or maims increasing numbers of people. The stroke, heart disease, cancer, obesity, hypertension, diabetes, and food-borne illness links to high meat diets are now inescapable. The message is clear – eating high on the foodchain severely damages one's health. Heart disease in the US alone costs

$66 billion in 1996 according to the American Heart Association. Much of this can be attributed to high meat diets. Cardiovascular disease need not be a consequence of living – if one reduces carnivory. A low-fat grain-based diet has now become the main therapy for the 1.25 million annual preventable US heart attacks.

THE RELIGIOUS ARGUMENT

Frugality, sufficiency, 'enough is best', moderation, simplicity, and asceticism are common themes in many religions. Stewardship and respect for God's creation need to be emphasized by religions. Scientists, even environmentalists, are taught that all life results from accidental recombinations of genes, random permutations, and accidental mutations – the raw material of evolution. Were this so, logically there could be little purpose in life, no persuasive virtue in living, no hope or promise for the future, hence no reason not to commit suicide except for materialistic gratification of the consumer in standard economics. The aim of environmental sustainability is to resolve the 'mortal combat' between environment and economics (Daly 1995a; 1995b). Sustainability is needed to reduce inequity, to protect people now and in the future, and to conserve life-support systems – environment – what is to believers the creation of God. Conservation of life-support systems depends on population stability and consumption. Moderation and sufficiency of many religions can be interpreted as requiring a stable population consuming sufficiently. The opposite – more people at a lower standard of living in a damaging environment – cannot be a goal of religions today. As virtue is by no means restricted to believers in God, atheists may also be persuaded by the frugality argument. One can love nature without being religious. Atheists also find great meaning in life.

Most religions preach frugality as a virtue and waste as a sin. But most societies today are run more by economics rather than by religion. Economics reduces people to materialistic consumers. Waste boosts the gross national product (GNP); frugality lowers it. What one consumes is unimportant in economics; more is better; more raises GNP; whether goods (food) or bads (defensive expenditures on police or pollution-induced disease) are consumed; whether wealth or ill-health results. Economics is inadequate on natural capital (= ± environment), because technology, it is hoped, will always find a substitute for God's creation. Natural capital can be consumed with no thought for the morrow because it can be substituted for in traditional economics.

Economics today focuses on marketed commodities, including manufactured capital, which was the scarcity or limiting factor of yesteryear. The new scarcity is the remaining natural capital, rather than manufactured capital. Fish and forests have become the limiting scarcities, not fishing boats or

BOX 1. *Life-style changes needed for environmental sustainability*

1. *Walking, biking, and mass transit* damage the environment less than driving automobiles.
2. *Extra blankets or sweaters* damage less than raising the thermostat.
3. *Opening windows* cost less than turning on air-conditioners.
4. *Insulation* costs less than firing up the furnace.
5. *Recycling* costs less than trashing.
6. *Durability* costs less than obsolescence.
7. *Large families* cost more than small families.
8. *Overconsuming* Northern families cost more than poor Southern families.
9. *Grain-based diets* are far more resource efficient than carnivory.
10. *Village agroforestry food plots* are more productive than agribusiness food.
11. *Prevention of pollution and waste* damages less than their treatment.
12. *Labor-intensive growth* environmentally costs less than capital-intensive growth.
13. *Most renewable energies* damage less than coal (and oil)

BOX 2. *To promote sustainability*

Rural priorities

1. Fuelwood plantations, including all roads, lanes, hedgerows, canal banks, and property lines
2. Tree seed collection and tree nurseries
3. Sapling distribution and maintenance
4. Fuelwood quasi self-sufficiency by all farms, villages, towns, bakeries, barracks, hospitals, schools, laundries, and prisons
5. Southern carbon-sink forests fully paid by the North
6. Alternative small-scale energy systems, such as solar, wind, and biogas
7. Intensification of food production: terraces, green manures, fishponds, small livestock
8. Perennial crops rather than annual cash crops
9. Wood processing: value-added, domestic processing from fuelwood plantation thinnings and from plantation forests
10. Water supply: improved wells, less distance, low-technology pumps
11. Social organizations and collective action by the poor to improve resource management

Urban priorities

1. Low technology sanitation; mulching toilets, and locally manufactured plumbing
2. Urban homegardens, balcony and roof gardens, and window boxes
3. 'Sweat equity' labor for beneficiaries
4. Sewage sedimentation lagoons, space permitting
5. Drinking water loss-reduction gains for slums
6. Promote cleaner slum fuels (methanol *versus* charcoal
7. Solar stove and solar cooker efficiencies
8. Garbage and biogas/methane digesters; garbage prevention rather than treatment
9. Fortification of flour
10. Promotion of sum cooperatives
11. 'Fair price' shops and 'fair trade': subsidized coarse grains
12. Health, hygiene, breast-feeding and family planning education campaigns
13. *Pro bono* medical aid: vaccines, oral rehydration
14. *Pro bono* legal aid to facilitate access to benefits and to buffer against usury and other abuses
15. Social organizations and collective action by the poor to improve resource management

sawmills. Most of the 'environment' falls outside markets (healthy air, biodiversity, and stable climate). Thus, it is 'externalized' by economics. Religion teaches that damaging God's creation is evil. Unsustainability must also be unacceptable as it means the environment is being damaged. Overharvesting means environmental regeneration rates are being exceeded. Therefore, both overconsumption and malnutrition must be construed as unacceptable or worse. Moving lower on the foodchain to grain-based diets helps both. Other fairly simple life-style changes and development options to foster sustainability are outlined in Boxes 1 and 2.

> *What comes out of one's mouth is more important than what one puts into it* (Mahatma Gandhi).

ENDNOTES

(1) These two services are the source function of the environment to provide raw materials for the human economy, and the sink function to absorb societies' wastes (Daly 1992a; 1992b; Daly, Cobb 1994.) The two functions are rates that can be estimated or measured. More specifically, sustainability means that the absorptive capacity of the environment to assimilate wastes (sink capacity) cannot be exceeded. Products must either be recycled or assimilated by the biosphere. Harvest rates of renewable resources (source capacity) must not exceed regeneration rates. For example, fishing exceeding fish-stock regeneration rates is a global pattern and has led to declining yields of practically all major oceanic fish stocks. Environmental sustainability is a rigorous, universal, and nonnegotiable concept, and is not at all subjective. Nonrenewable stock resources, such as oil and minerals, are more difficult to make sustainable. Serafian quasi-sustainability for nonrenewables has been widely accepted (El Serafy 1989).

The most fundamental requirement of environmental sustainability is that capital should remain intact. This requirement must be applied to natural as well as to fabricated capital. Counting capital consumption as if it were income is the greatest of all accounting sins (El Serafy 1996a; 1996b). Consumption of either natural or manufactured capital reduces future capacity to generate income. In order to approach environmental sustainability, economic analysis needs to employ the concept of user costs systematically in all projects using environmental services (sources or sinks).

Depletion of natural capital (nonrenewables such as natural gas and minerals including oil) as well as renewables (forests, fish, clean air and clean water, capacity to assimilate wastes), specifically including the regenerative and absorptive capacities of the environment, must bear a user cost. There is an opportunity cost involved in depleting the capacity of the atmosphere to absorb carbon dioxide, for example, as well as the depletion of coal mines or oil wells. Disregarding user cost is equivalent to counting it as zero, which leads to an overestimation of the rate of return. This introduces a systematic and pervasive bias in the allocation of investment capital against sustainable development. Omission of user cost promotes projects which deplete natural capital and demotes investments allocated to restorative or sustained-yield projects. If no royalties are imposed on mining, or if timber on national lands is sold below cost, depletion of natural resources will intensify, and sustainability will recede.

(2) Stable human populations are fundamental for environmental sustainability. Each human needs an irreducible biophysical minimum of c.2000 calories of food, plus fuel to cook,

clothes, and shelter. The world can provide more than such minima if overconsumption by the affluent is reduced. This would improve the health of the affluent, and reduce global environmental risks such as climate change, ozone shield damage, pollution, and deforestation. The relationship between population and consumption (Impact = Population × Affluence × Technology) suggests that the first two terms need to be decreased or at least held stable, while optimists expect most reduction of impact on the ecosphere to come from improved technology. Most countries have now reversed pronatalist policies. Most promote family planning, maternal health, and education of girls. These will assist in achieving the top priority of sustainability, namely, a stable population. This is one of the most important life-style changes necessary for sustainability. Populations have to stabilize fast, especially in the overconsuming nations of the Organization for Economic Cooperation and Development (OECD). As the environmental impact of one OECD overconsumer is one or two orders of magnitude greater than that of one person from a developing country, population, including immigration, must stabilize fast in OECD countries. In the future, as 90% of population increase will come from developing countries, population stability is essential there too. About 0.5 ha of cropland/capita is needed to provide conventional diets, but only half that (c.2.5 ha) is currently available, and this is declining. The balance comes from food imports. This highlights the urgency of stabilizing population.

(3) Much of this information is taken from the detailed analyses of Pimentel (1994), Pimentel, Giampetro (1994), and Kendall, Pimentel (1994). Of course, there is much uncultivated land, particularly lands taken out of cultivation to keep farmers' prices high, as in the US and EC. But much of this land is marginal, that is why it was taken out of production in the first place. It can support much wildlife. Unfortunately, marginal lands will probably be brought back into cultivation. Their contribution to food production will be marginal and unsustainable due to erosion or whatever the other constraints were. Erosion forces abandonment of about 10 million ha, and exceeds topsoil regeneration rates by 16 to 300 times. About 0.7% of the world's total topsoil stock is lost annually. This means 30% of the topsoil will be lost by 2050 unless erosion is slowed or halted.

(4) The only cropland not degrading rapidly is paddy-rice land. Erosion in Iowa is about 30 tons/ha/year, while the sustainability level is 1 ton/ha/year (Pimentel *et al.* 1995). During the last 40 years, nearly one-third of the world's arable land has been lost by erosion and continues to be lost at a rate of more than 10 million ha per year. Land abandonment due to erosion is increasing because of the trend to burn more crop residues for cooking and heating. More than one-third of all biomass fuel in developing countries is now crop residue. This trend is devastating agricultural soils (Pimentel 1996.)

(5) Biotechnology is thousands of years old. Many early histories mention well-developed brewing and wine manufacture. Antibiotics and vitamins have been manufactured by fermentation for half a century. Genetic engineering began in the 1970s and is, therefore, about two decades old. The groundwork has been laid, especially now that recombinant DNA is becoming routine and reliable *in vitro*, so transgenic plants are widely available. The promise of enhancing crop plants to withstand bacterial, fungal, viral, and insect attacks, as well as environmental stress, could exceed the benefits of the Green Revolution. Although genetic engineering is promising, it has not yet produced much of substance for world food supplies. Some biotechnology may, in the future, help the poor, but is it likely to do so as well as research that starts with the needs of the poor as the point of departure (Kloppenburg, Burrows 1996)? Genetic engineering is expensive; it has consumed of the order of a billion dollars so far, mainly by the private sector which has to

recoup that investment. This suggests that most achievements of genetic engineering are more likely to benefit those who can pay rather than to reduce food prices or increase yields to benefit the poor. Genetic engineering so far has prolonged flavor for an additional three to five days in the élites' tomatoes (Calgene's 'Flavr Savr' cost $25 million). Monsanto's $0.5 billion investment has increased resistance to Monsanto's 'Round Up' biocide so that more can be used without killing crops, mainly cotton and tobacco. Development of the Bovine Growth Hormone cost $300 million, but doubts about its health and safety has forced Europe to constrain such imports from the US.

(6) Aquaculture has two extremes. Low productivity and low impact aquaculture depends on autotrophs (green plants, plankton, algae, etc.) for nutrients to feed whatever the crop is. High productivity and high impact aquaculture depend on inputs of feed (sewage, agricultural residues, 'by-catch' fish meal). This is more productive from the same area, but expensive in terms of the environmental impact for the feed, diesel, pumps, transport, etc. Fish farming is more productive than producing beef. Fish need only 2 kg of feed per kg of liveweight gain, compared with 7 kg for beef. Aquaculture, a $30 billion industry worldwide, is valuable in producing protein and recycling waste. Fish ponds recycling sewage into protein should be promoted more than at present if sustainability is to be approached. The products are valuable and palatable if appropriately cooked or kept in clean water for a couple of days before cooking. Clean water is often the main constraint for the expansion of aquaculture. The main source of aquaculture feed is the 'by-catch' of ocean fisheries. That source has been unsustainably harvested and is declining. Aquaculture competes with cattle for such feed; however, it is normally preferable to feeding cattle as it is more productive at a lower impact. Aquaculture merits more attention in the world food effort than cattle raising. Many fish are actually carnivores or piscivores as they eat the fish which feed on plankton. About two-thirds of aquaculture is done in freshwater, rivers, lakes, ponds, and tanks; the rest is coastal mariculture which is ripe for a major expansion. About 25% of shrimps are farmed and many from converted mangroves which is the major impact, and decreases offshore fish catches. Today, global aquaculture produce (16 million tons) could meet 40% of the world fish demand within 15 years (Brown, Flavin, Kane 1996).

(7) This is a subset of the broader issue of environmental sustainability in agriculture. This exceptionally important issue is in urgent need of analysis as there is little consensus to date (FAO 1995; 1996). Pimentel (1996) notes that 'the only agricultural system that is sustainable is slash-and-burn. However, there are few places in the world where there is sufficient land to practice slash-and-burn agriculture – approximately 20 ha are needed in fallow for every 1 ha in production. Overall there is a trend to less sustainability, especially when soil productivity is taken into account.' All measures to promote sustainability should be first accompanied by strenuous efforts to stabilize populations of overconsumers (in both developed and developing countries). Promotion of organic farming and phasing out of fertilizer, biocide, and diesel subsidies would be enormously effective in reducing pollution and the environmental costs of agriculture. Achieving sustained yield (S-Y) will be difficult; achieving environmental sustainability (ES), much more so. The differences between S-Y and ES are similar to those between simple wildlife and complex biodiversity. ES includes, but is far from limited to, S-Y. ES is akin to simultaneous S-Y of many interrelated populations in an ecosystem, not just a few species of timber trees, a species of fish, or a few species of mammals. S-Y is ES restricted to a small fraction of the components of an ecosystem. S-Y determines the most profitable extraction rate for a timber tree species, or a fish, or a mammal, and counts only the resource extracted. ES counts all species and all services provided by the ecosystem and holds it to-

gether, such as protecting vulnerable ethnic forest dwellers, carbon sequestration, intrinsic as well as instrumental values, genetic biodiversity, climate moderation, and ecosystem integrity. The optimal solution for a single variable, such as S-Y, usually, and possibly inevitably, results in declining utility or declining natural capital. In such cases, S-Y is not sustainable.

(8) This is a generalized ranking, mainly of commercial foods. Clearly, a simple rank cannot precisely optimize on the three criteria of efficiency, impact, and sentience, but the generalization is robust. Impact and efficiency can be measured or estimated; sentience less so. Sentience seems to be related to the complexity of the nervous system. While it is anthropomorphic to interpret a cow's screams, bellows, and writhing as it is hurt or killed as being pain, such sounds and movements are so similar to humans in the same circumstances that it seems reasonable. Some mammals (e.g., dogs) seem to be hurt by harsh human voices. Cold-blooded animals have simpler nervous systems and probably do not feel pain as we do. The story of the fish losing its eye to a fouled hook and then seconds later eating its own eye as bait suggests different pain thresholds. Presumably a bisected worm hurts to some extent until each half regenerates. The range of animals that humans find worth conserving is increasing. Charismatic megafauna (e.g., elephants, tigers, gorillas, great whales, etc.) and the cuddlies (e.g., pandas, koalas, baby seals, etc.) are obvious examples of the mammals. Marine mammals and turtles are regularly discriminated against by the World Trade Organization [ex-General Agreement on Tariffs and Trade (GATT)]. Bats and toads have their advocates too. In the US, there is an affluent movement to conserve bat roosts in disused rail tunnels. Hedgehog and amphibian road crossings are marked in some European communities. The industry now manufactures canned food expressly for wild hedgehogs in UK. Bees have been semidomesticated for millennia for their utilitarian value. Spectacular butterflies are conserved in many countries and figure in Papua New Guinea's constitution. The overwintering pine forest patch for the Monarch butterfly in Michoacan, Mexico, has had a gold medal and stamps bearing its image, as well as more than one society dedicated to its conservation (Monarca S A). Some municipalities (e.g., Olching, Bavaria, etc.) switch street lighting from insect-killing mercury vapor to sodium 'insect-friendly' lights. This is interesting as it conserves flying insects, in general, and nocturnal ones that are not familiar to most people. The World Health Organization (WHO) and its ethics committees agonized whether to cause the extinction of the smallpox virus – one of the biggest killers in history – for decades after the last naturally occurring case had been cured (Mr Ali Maow Maalin of Merca, Somalia, in October 1977). Edward Jenner first made and used the vaccine in 14 May 1796, but the virus attacked up to 15 million people a year as recently as the 1950s–1969s. The last few (nonfatal) of cases were accidental escapes of the virus from laboratory cultures. The virus is now confined to two laboratories in Atlanta, USA, and Koltsovo, FSU. Now that the genetic structure of the virus has been fully analyzed, its DNA cloned, half a million vaccines stockpiled, and the similar but relatively harmless *Vaccinia* virus is conserved, WHO has decided to cause the extinction of the smallpox virus on 30 June 1999. These precautions set precedence for human-induced extinctions. Such microbes must be very low on any scale of sentience, although one cannot rule out its anthropocentric utilitarianism for the future.

Primates from the wild are widely eaten throughout Africa, for example, and would top the rank in sentience. *Swine* are worse than cattle because although their conversion efficiencies are similar; cattle eat grass for some period of their lives before they are fattened on grain. Where pigs feed exclusively on household wastes, thus recycling what would otherwise pollute, they have a useful role. All *cattle* are not equal. Pastoral cattle (e.g., Maasai, Tuareg, Bedouin) eating range too dry to cultivate impose the least impact. The ruminant ability to digest cellulose can thus be valuable. In view of human overpopulation, there seems to be decreasing room for pastoralism in today's world, just as there is decreasing scope for shifting cultivation. We have let human population pressures undermine their sustainability. Drinking blood/milk mixtures without killing the cow seems preferable. Most beef cattle eat grain at least in the latter part of their lives. Much animal feed comes from manihot (i.e., cassava, tapioca), a starch crop widely eaten throughout the world and a staple food in South America and Africa. Most feed manihot is cultivated in areas where forest was destroyed to create the plantations and, hence, has vast environmental costs. Draught traction from one cow (FAO 1995) can be useful on small farms, especially if they do not eat grain. Their manure, and the biogas derived from it, play useful roles in many villages. Their milk helps children and can provide income. Of course, this implies brief lives for most bulls. There may be niche roles for specialties such as buffalo raised only on range, because such meat is so low in cholesterol. More than 20 million white tailed deer are hunted annually, probably sustainably, in the northeastern US alone, now that their predators (wolves) have been removed. But venison is unlikely to contribute much to global food balances. Gandhi used *leather* to make sandals, but only from cows dying of old age. As *goats* climb trees and browse, they are placed above *sheep* in this ranking. *Birds* showing conjugal fidelity (e.g., geese) appear distressed when their partner is removed. The remaining goose vocalizes more frequently and appears to search for its former mate for a week or more. Chickens appear more indifferent if one of the flock disappears. *Lagomorphs,* rabbits, and hares, are now separated from *rodents.* These include agoutis, cane rats, guinea pigs, rats, mice, and hamsters. *Fish* used to be the main protein source of the poor, and still is in some countries (e.g., Bangladesh). Global fisheries are practically in decline and fish prices are so high that the poor can no longer rely on that source. At the extreme (to date), some tuna exceeded $1000/kg in Tokyo 1995. Other seafood normally exceeds fish in price and is also ruled out as much of a hope for the poor. Among the *invertebrates,* krill may have a future role if people can be induced to eat it. Some people will eat sessile invertebrates (e.g., limpets) but not motile ones (e.g., shrimp). This is understandable as the removal of one limpet does not seem to cause suffering in other limpets nor does it damage the limpet community. Limpets communicate to a limited extent, but don't seem to socialize. Their propagules drift from the parent to a suitable substrate where they affix and remain for life. Fish certainly communicate within the shoal and some may react if one is taken. *Insects* are the widely consumed grasshoppers and locusts, termite grubs, and silkworms, for example. *Honey* is not strictly secreted by bees, being regurgitated, but is not used by vegans.

Green plants are the most efficient foods as they are autotrophs; they grow by manufacturing their own food from air, sun, water, and nutrients. Most *plant foods* are among the highest evolved plants; most are angiosperms. The two big food families are the grasses (e.g., rice, wheat, and maize) and the legumes (e.g., soyabeans and pulses). Indonesia introduced or promoted fermented soyabean products (*tempeh*) a decade or so ago specifically in order to improve food security. Algae, fungi, and yeasts are the main foods lower on the evolutionary scale. Many *microbes* are saprophytes; they grow by feeding on dead animals or plant material. Microbes include yeasts and starches fermented into more nutritious products, such as miso and Marmite™. Some people (Christian scientists) refuse immunizations made from killed microbes, but may be indifferent where they eat on the foodchain. They distinguish between injecting substances into their bodies with assimilating substances via their mouths.

(9) Congruence between the sentience and the ecosystemic scales is increased when biomass is used in the comparison, rather than individuals of a species, such as one tree or one

gnat. The impact of removal from a forest of a total biomass of gnats equal to the biomass of one tree probably exceeds the removal of one tree. Michael (1996) writes that a pesky fly has intrinsic value and questions whether we should swat it. He writes: "Biocentrists agree that things with intrinsic value must be treated equally; to do so amounts to speciesism." Probably I am guilty of speciesism throughout this paper as I am positing that there is a ranking on several criteria, including ethical. That is partly why vegetarians eat plants and try not to kill animals.

(10) Humans are omnivores, not obligate carnivores. Probably, humans were originally foragers subsisting on fruits, seeds, and tubers; eggs and easy-to-catch animals were probably scavenged as part of the diet. Hunting and domesticating animals came later in human evolution. Luke (1995) refutes the atavism argument that hunting is instinctive, and therefore, exempt from moral valuation. Our compassion also argues against innate predatory instincts. Humans do not need to eat flesh to stay healthy, according to the Nobel biochemist laureate Konrad Bloch (1994). Clearly everyone needs to balance their diet, including vegetarians. The amount of protein (plant or animal) that humans need for health is small although not precisely known; 0.8 gm/day is on the high side for a healthy adult; adults consuming 0.5 gm/day are fine, but this is too low for an average. Young children, the poor, and the unhealthy need more. Raptors are obligate carnivores, and must eat flesh occasionally. Two carnivores, the Giant Panda and the Black Bear, have become herbivores; the Panda eats only bamboo. Domesticated dogs are not obligate carnivores, although their ancestors were. Little is known about the genetic basis of obligate carnivory, except in the domestic cat. Retinal deterioration leading to blindness in cats artificially deprived of the amino acid taurine and vitamin A eventually go blind (Bloch 1994). Omnivores and herbivores can synthesize taurine, though there is some evidence that taurine deficiency in primates produces less than optimal growth. Brown (1996) points out that millions of years of hunting and gathering seem to have evolved into humans' strong liking for meat. There seem to be no allergies to eating mammalian flesh, as there are for dairy, partly because dairy is so recent in evolutionary terms. Allergies to shellfish suggest humans have been eating shellfish for longer than mammalian flesh. Most Asians are lactose intolerant.

(11) In this conceptual paper, the precise methodological nature of the incentives is left to economists. Removal of livestock subsidies, education campaigns, reallocation of R & D investments away from cattle and towards grains, starches, fruits, and legumes should be the start. Presumably the meat inputs (water, diesel, grain) could be taxed. Beef sales are the US' largest revenue source in the whole agriculture sector. Only four meatpackers in the US hold 82% of the market, so that might be a low-cost place to tax. Incentive methodology could address taxing feedlots, ranchers, or slaughter houses. The US' 104 million-strong cattle herd is the largest single user of grain, mainly in the form of winter feedcakes or pellets. Possibly that can be taxed. In some counties, livestock account for half of the taxes. Presumably this could be raised. Or, a landuse intensity tax would foster intensification and demote extensification, such as ranching. Taxing grain as an input for cattle would be difficult to discriminate from human food use. If taxing grain becomes necessary in the future in order to foster only its most efficient uses, such a regressive tax should be balanced into neutrality by reducing income taxes commensurately. Higher priced grain would then automatically go to the more efficient users, namely, feeding people.

(12) Cohen (1995) assumes that 10 kcal of feed are needed for every kcal of energy consumed, then the amount of edible food energy that would have to be grown to supply ev-

erybody with 2500 kcal would be 0.7 × 2 500 (for the vegetable portion of the diet) + 0.3 × 2 500 × 10 (for the animal portion) = 9250 kcal.

13) Many people bury their dead pets (goldfish, budgerigars, cats, etc.) in the garden or the farm so the nutrients are recycled. Isolating human carcasses from recycling by sealing them in coffins and marble tombs decreases sustainability. While current taboos on cannibalism or eating dead relatives are understandable, the question is one of timing. Few balk at eating mangoes from the tree planted on the grandmother's grave; yet many would at feeding dead relatives to the family pig. Swiss obstetric hospitals halted their practice of feeding human placentas to animals in April 1996. Zurich Environment and Health Department Head, Ursula Vettori, said it is 'ethically outrageous'. Humans in some countries are said to prize them as a therapeutic food. If human placentas can be fed to cattle in advanced or thrifty Switzerland, what is the logic in stopping cadavers being fed to cattle? Where the recycling is short or obvious, people start to doubt. OECD's wasteful and dangerous trend to convert herbivorous livestock to carnivory and even to necrophagy or cannibalism has backfired. Many dead animals are now ground up for livestock feed, hence the November 1986 outbreaks of scrapie and the 'mad cow' disease [bovine spongiform encephalopathy (BSE) which includes scrapie and its devastating human form, the Creutzfeldt-Jakob disease] in Europe (France, UK, and Switzerland, at the last count), leading to the March 1996 banning of British and Swiss beef (Dealler 1996). BSE may eventually cost UK £5 billion sterling. As of mid-1996, 160 000 BSE cases have been reported in UK (none south of the Eire border). Vertical transmission from infected pregnant cows to their offspring has been detected. BSE or analogous encephalopathies may have been detected in mice, mink, and a few antelope in UK. Even the export ban on tallow, gelatin, and semen has not been lifted as of June 1995. Now many UK cattle are being incinerated. It is not easy to get rid of one million cattle. Burial is not an option as adequate landfill sites have run out. There are too few incinerators for immediate burning. Most are disposed of by rendering, in pressure cookers, into tallow (formerly sold to soap powder and cosmetics industries) or grieves (meat and bone meal formerly sold for animal feed). Now that such uses are banned, they may be disposed of in power stations. As this may clog the stations, and as the smoke will be smelly or unhealthy, mountains of tallow and grieves are piling up. Pigs and poultry also may harbor BSE and may pass it to humans. As UK exports of cattle feed tripled the year after UK banned the use of animal remains in its own domestic market, BSE should be expected to appear in the countries (mainly EU) that imported such products. This, and recent outbreaks of the Ebola virus in Africa and the US, are likely to support the case against the use of animal (sheep or pigs) organ transplants especially from primates (chimpanzees or baboons). Such xenotransplants (kidneys, livers, hearts, bone marrow, and brain tissue) increase the risk of humans becoming infected with animal diseases, especially viruses and prions. BSE may be transmitted by hay mites carrying the BSE prion. This is consonant with scrapie being found in pasture. Cremation is environmentally inefficient as it wastes organic matter and all volatilized nutrient minerals, such as phosphorous, sulfur, and nitrogen. Cremation is now Scandinavia's prime source of mercury pollution, which is emitted when the dental fillings of the dead bodies burn. Caging chickens over fish ponds, draining pigsties into fish ponds, raising fish in sullage cages by the roadside as in Indonesia, or siting the pond just below the privy leachfield, are highly efficient and can be sustainable.

Killing humans for sport was practiced until fairly recently. For example, the Supreme Court in Colombia ruled that it was illegal to hunt Amerindians in 1972, but the perpetrators were acquitted. Dominican Friar Bartolome de las Casas (1474–1566) had made the case to King Charles I of Spain that Amerindians were humans rather than subhuman or bestial (Goodland 1982). Weekend sport hunting of Australian Aborigines ended early in the 1900s. They were ruled as humans in the 1950s, and became citizens in 1960. US Amerindians were granted US citizenship in 1924. The death penalty for humans convicted of environmental crimes may increase. Some countries kill humans for log poaching (e.g., Thailand); China imposes the death sentence for 'serious environmental damage'. Proposals to limit population pressures by culling humans are fortunately rare. For human populations, we prefer to limit birth rates, rather than to cull. But assisted euthanasia is now accepted in the Netherlands. This acceptance is increasing in several countries. Dr Jack Kevorkian (physician; retired from the Michigan Public Health System) is testing the limits of societal acceptance of assisted suicide (*assiste suicides*) and euthanasia to relieve suffering in the US. Recent US court rulings have lifted the ban on assisted suicides. Suicide should be more of an option than it is today. No one has the right to keep a vegetable-like body alive as long as possible, especially when the life is meaningless or painful (Cobb 1991). One misgiving is that should euthanasia become widespread to relieve suffering, would it become more likely for population control: culling humans? Proscriptions against cannibalism (eating humans before natural death) seem widespread and little questioned. Necrophagy is also rare, but with less logic. Organ-donating upon death has become accepted; exsanguinating recent corpses for the transfusion bank, however, has not yet gained acceptance.

(14) For amplification, see Dizard (1994); Hargrove (1989), Norton (1986, 1987), and Taylor (1986).

(15) There is little discussion on how serious the wound has to be to justify killing the animal. Wounding gravity probably varies with the animal in question; any wound from a crocodile would probably be used to justify its death. An elephant treading on a human's foot or knocking someone off balance probably might not. As elephants learn quickly and lose fear of humans after one 'successful' encounter, even small damage to humans by elephants can escalate fast. A notorious individual elephant with a taste for raiding or one known to be a habitual offender damaging crops, fences, and other property would also be killed. How much damage and over how long a period is not clear. Similarly, hyenas harassing and occasionally killing humans would be shot, whether they kill cattle or not. As hyenas cooperate in packs, the one-to-one justification is impossible, so this weakens the moral principle of proportionality, and only partly meets the principle of self-defense.

(16) Using elephant tusks is problematic as the ivory ban is still in place. Presumably, if and when elephant populations are allowed to restore themselves to resilient sizes, and when controls work well, then the use of rogue elephant tusks or tusks (now stored in countries where the ban is still in effect) from elephants dying of natural causes may be permissible and profitable.

(17) Example: (i) if zebras are shot by the landowner to provide meat for a party when the range was not deteriorating, that could not be culling. If the range was deteriorating, killing the zebras for meat could be construed as both culling and hunting; (ii) if a landowner is unable to shoot when culling is necessary, the landowner may hire a professional hunter to kill a specific number of a certain species; (iii) an elderly widowed landlady may request a neighbor to cull by hunting. The fee for this professional service may be reduced or waived if the hunter is allowed to keep the products. Presumably, if the professional hunter wants the products greatly, and the landowner knows culling is necessary, the hunter may pay the landowner; (iv) a hunter may ask a landowner for permission to shoot some animals when culling is necessary.

(18) As Hopcraft's 30-year old Athi river game/meat ranch in Kenya shows, it has not yet been able to make game-meat production as profitable as beef production. Certainly, if foreign (e.g., Rockefeller, Ford) scientific research grants continue to be available, the experiment is worth continuing. The facts are that one zebra consumes about twice as much fodder as one cow. The market does not reveal twice the price for zebra, and for less meat per animal. Zebra meat is often sold for half the prevailing beef price, and giraffe meat for slightly more than beef. Although supportable wildlife biomass (excluding zebra) may exceed that of cattle, game meat has never been made more profitable. Over the long term, probably mixed cattle/game ranches will turn out to be more sustainable, and hence a better solution.

(19) Much of the sections on trophy hunting and killing for meat rely heavily on Brian Luke's comprehensive and thoughtful 1995 essay.

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VALEDICTORY ADDRESS

Tim Wirth[1]

Ladies and Gentlemen. Most of you here today know more about the issues of population, environment, and development than I would ever begin to know. I thought it would be useful to give a brief outline on the population issue, which many of you work on. The issue touches upon just about everything and the new US foreign policy is also attempting to address this absolutely crucial issue.

The Cairo Conference in 1994 paved the way towards building population into a high priority area for the country. I don't think that we have ever been in a situation like this before, where population was seen as a central issue.

In the midsummer of 1994, we had a major dinner meeting on the eighth floor of the State Department, which few of you attended. President Clinton had agreed to address the gathering. We had drafted the speech that he had to deliver. The speech went through several stages of corrections, and by the time the final draft was put together, it had some fundamental mistakes in it. The person who had been our number one advocate on the White House Staff asked us to warn the President in advance. So, when the President came in, three or four of us went up to him, and asked him if we could take a look at the speech. He, instead, pulled out a speech, drafted in his own handwriting, very closely along the lines of the original draft, addressing all the problems. This was clearly reflective of the President's enormous intellectual understanding of the subject.

The focus of that speech helped us enormously as we are now trying to introduce a much greater understanding of the politics of population into our regional bureau, and to explain that it is imperative to think of population stabilization. The concept that economic development is the best contraceptive is an idea that sounds good if it is said fast enough. The reality of the situation, however, is that, in too many parts of the world, we see population outstripping real economic development. And, this gap is getting worse. Those of us who are concerned about the preservation of the environment are also aware that population growth and development have a bearing on the environment.

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We are also spilling out into two other major priority areas – the issues of international health and food security. In the international health area, the question of emerging and reemerging infectious diseases is now a major priority. Even at a time of very difficult budgets, we are working hard with the World Health Organization, the Centre for Disease Control, and the US Agency for International Development to strengthen the network related to the control of infectious diseases around the world. The second issue is that of food security and starvation. Last fall, the Central Intelligence Agency and the Department of Agriculture brought out a very good piece on long-term food security, which emphasized that the food issue is more than one of distribution and storage. There are some fundamental problems, resulting from variables such as subsidies, storage, surpluses, and prices.

On a final note, I would like to mention the document brought out by the President's Council on Sustainable Development, of which Jonathan Lash was the co-chairperson. This document is the US response to Rio. The document has a very strong statement on the population of the US in the chapter on population and consumption. While looking at population problems around the world, we need to realize that there are significant population problems right here in our own backyard. The population of the US is growing at the rate of about 3 million a year. A million of that comes from immigration and 2 million from the existing population. We need to consider the impact of consumption among American consumers. A child born in the US, over his lifetime, would consume 30 times more resources than a child born in Calcutta or Shanghai. An increase of 3 million a year in the US population, with 30 times the consumption of an average person in the developing world, would have an impact equivalent to that of 90 million people. This is not a perfect parallel, by any means, but it is certainly illustrative of the impact and importance of the US populace, as well as in terms of the responsibility of the US to the rest of the world with regard to its own population growth.

It has been absolutely fascinating to have the opportunity to discuss some of these issues with you here today. Thank you.

EPILOGUE[1]

Lubina F Qureshy[2]

This volume has addressed a diverse set of issues covering poverty,[3] food security,[4] consumption patterns, energy use,[5] global warming,[6] biodiversity, water scarcity, speculations on the number of people the earth can support,[7] and the dynamics of conflict arising from population and environmental stress.[8] An important question raised at the conference was whether these problems should be viewed as global problems to be resolved at the international level, or whether they should be viewed as local problems to be addressed by policies designed by national governments. Some of these issues, for example, global warming, transcend political boundaries, and need to be resolved at the international level. Other problems, such as soil erosion and water and air pollution, need to be addressed by policies at the national level.

In practice, it is not always feasible to segregate problems on the basis of whether they should be addressed at the local or the global level. Loss in biodiversity might be localized in the immediate future, being confined largely to tropical forests, but in the future this is a loss to humanity at large (Bhaskar, Glyn 1995). However, apart from the level of redress, what is irrefutable is the fact that it is essential to have country-specific and location-specific analysis in order to generate policies closer to ground realities. These micro-level actions could, in turn, be linked to strategies at the macro level.

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[1] This epilogue is largely based on the discussions on the papers presented at the Conference. The list of chairpersons and panelists is presented at the end of this paper.

[2] Tata Energy Research Institute, Darbari Seth Block, Habitat Place, Lodhi Road, New Delhi - 110 003, India.

[3] The *'Second India' revisited: population growth, poverty, and environment over two decades* by Robert Repetto.

[4] *Environmental sustainability: eat better and kill less* by Robert Goodland.

[5] *Fueling the world's largest population and a fast-growing economy: the Chinese experience* by Yingzhong Lu.

[6] *Population, development, and global warming: the international institutional challenges ahead* by Frederick Meyerson.

[7] *How many people can the earth support* by Joel Cohen and *Population as a scale factor: impacts on environment and development* by Robert Engelman.

[8] *Population dynamics, environment, and conflict* by Ismail Sirageldin.

One issue of prime concern, discussed at length at the conference, is that of global food security. On the one hand, the problem is that of being able to produce larger and larger quantities of food for an increasing number of people. On the other hand, the solution to the problem of feeding the millions cannot be achieved by merely bringing about larger increases in food production. What is required is a more equitable distribution of the produce, and to ensure adequate nutrition for all. This implies a reappraisal of global food distribution. In many countries, the problem of hunger is a result of inequitable distribution of production assets, unemployment, and underemployment. And, therefore, it is the immediate task of the national governments to formulate policies that can rectify these inequities.

A much debated issue is that of the contribution of poverty to population and environmental stress. While it is recognized that poverty exacerbates environmental stress, it is important to identify the causes behind this. The link between poverty and the environment can be broken by attacking the issues at the root of the problem, as brought out in some of the papers in this volume.[9] For example, it is believed that the poor prefer a larger number of children, as each child is an additional source of income for the household. One way to counter this thinking is to grant the poor access to resources or to other means that can generate income. It is essential to note, however, that many rural families are realizing the importance of small families and the high costs of raising children. But poor contraceptive delivery services and medical follow-up are major constraints in allowing these families to limit their family sizes.

It is believed that population pressure accelerates the rate of deforestation. However, the true cause of deforestation, in addition to factors such as migration and commercial felling,[10] lies in the inequity in land distribution and access to arable land, that forces the poor to inhabit marginal lands, thereby reinforcing the cycle of poverty and degradation. Policy prescriptions should, therefore, include land reforms, alleviation of poverty, and the recognition of the rights of indigenous peoples. Any policy on deforestation and biodiversity should not be formulated in isolation of these issues.

Many rural communities are increasingly concerned about environmental degradation due to their close interaction with the natural resource base, upon which they depend for their sustenance. Policy makers should be better informed of the diverse efforts of the rural communities in dealing with growing population and deteriorating environmental conditions. With a clearer understanding of the adaptive strategies of the poor and the perceptions of the community, it would be possible to develop policies suited to the local environment. Fostering community participation and devolving authority to indigenous peoples would, in fact, be an effective means of conserving and managing the natural resources.

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[9] *Effects of population pressure and poverty on biodiversity conservation in the Philippines* by Maria Concepcion J Cruz and *Population, environment, and development: interactions and issues* by Paris William Reidhead, Lubina F Qureshy, and Vishal Narain.

[10] *Perceptions on community participation in population and environment in transmigration areas: a case study of Lampung, Indonesia* by Djuhari Wirakartakusumah and Mundiharo; *Population and environment interrelationships: the case of Nepal* by Bhim P Subedi; and *Population, development, and environmental conditions at the village level during 1981–1991: an empirical study using census data in Kota district of Rajasthan state, India* by K Srinivasan and Sanjay Kumar.

On the other side of the debate over poverty as a factor of environmental stress is the issue of unsustainable consumption patterns, a hallmark of the life-styles11 followed in the North and in the affluent pockets of the South. Even though it might be difficult to curb such high consumption levels, this is imperative for sustainability. This change, however, can occur only in the long run. In the short run, one alternative is for firms to switch to more environmentally benign production technologies (Schor 1995). However, in the ultimate analysis, a decline in consumption levels would only be possible with changes in attitudes at the individual level. Attitudinal change, in turn, would have to be preceded by environmental education and awareness. Thus, social perceptions should not be overlooked in policy making and developmental efforts should not be undertaken at the cost of social priorities.[12]

The concept of water stress and the issue of equal access were also well articulated at the conference.[13] Water could be the major source of conflict and war in the future; elements of distress are already visible in the Middle East. The level of water stress crucially depends on how efficiently water is utilized, especially for agricultural purposes. Primary emphasis was laid on improvements in the efficiency of water use. Suggestions were made towards devising a new technology for water use, changes in life-styles, improvements in distribution efficiency, and the use of recycled water for irrigation.

As it emerged from the papers and the discussions at the conference, the aforementioned issues should be addressed not as problems of the North or the South, but from the perspective of North–South and South–South relations. Technological innovations should be made more easily available in different parts of the world, and this should be fostered by building partnerships among governmental, nongovernmental, and private organizations across the globe. In order that local environmental concerns and aspirations are not neglected in the search for global solutions, increasing importance should be granted to grassroots organizations.

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[11] *Life-style and Technology: how much difference can they make?* by Faye Duchin.

[12] *The Tehri Dam project and the issues of population, development, and environment* by Ashish Bose.

[13] *Human population and water: meeting basic needs in the 21st century* by Peter Gleick and *The long, dark shadow: population, water, and peace in the Middle East* by Thomas Naff.

Although this book has attempted to address several problems related to population, environmental stress and the issue of sustainable development,[14] there are many dimensions to the population–environment–development nexus that remain unexplored. We, however, hope that this volume would make a modest contribution to the ongoing dialogue on these issues.

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[14] *Luncheon address* by Herman Daly.

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